PROGRAM For 1957 TECHNICAL CONFERENCE FOR REA FIELD ENGINEERS (ELECTRIC)

January 14 - 18, 1957

Jung Hotel
New Orleans, Louisiana

Program Committee: John F. Atkinson, Chairman, George H. Cole, Hans Hoiberg, James R. McCalman, W. E. Rushlow and Edward E. Warner.

U. S. DEPARTMENT OF AGRICULTURE

Rural Electrification Administration

MONDAY, JANUARY 14

Morning Session, 8:30 a.m.*

Jung Hotel

R. P. Stokely, Presiding

Opening Remarks	J. E. O'Brien, REA
Towards Better Service Reliability.	L. B. Crann, REA
Discussion	C. A. Campbell Louisiana Power & Light Co. New Orleans, La.
Discussion	Howard Evans Delta Electric Power Assn. Greenwood, Miss.
Discussion	Don Lowery, REA
Possibilities of Nuclear Reactors on REA Cooperatives	Wade M. Edmunds, REA
Discussion	Wm. C. Morris, REA (To be presented by John F. Atkinson)

*Registration will begin at 8:30 a.m. The Monday morning session will start at 9:00 a.m.

MONDAY, JANUARY 14

Afternoon Session, 2:00 p.m.

Jung Hotel

G. L. Woodworth, Presiding

Operations and Maintenance Practices	ᴗ. J. Gajan Southwest Louisiana Elec. Membership Corporation Lafayette, Louisiana
Discussion	A. A. Lee, REA
Discussion	J. W. Carpenter, REA
Safety and Job Training	A. B. Shehee, REA

TUESDAY, JANUARY 15

Morning Session, 9:00 a.m.

Jung Hotel

E. L. Arnn, Presiding

Aluminum Alloy Conductor in Distribution . . .	J. B. Roche Kaiser Aluminum & Chemical Sales, Inc. Chicago, Illinois
Inherent Design Factors in Connecting Aluminum Conductors	C. G. Sorflaten Kaiser Aluminum & Chemical Sales, Inc. Chicago, Illinois
Discussion	C. M. Wagner Nueces Elec. Coop., Inc. Robstown, Texas
Discussion	J. N. Thompson, REA

TUESDAY, JANUARY 15

Afternoon Session, 1:00 p.m.

Field Trip to Kaiser Aluminum Port Chalmette Works*

Inspection of Aluminum Pot Lines and
Electric Generation Facilities . . . . Kaiser Aluminum &
Chemical Sales, Inc.

*Chartered buses will leave the Jung Hotel promptly at 1:00 p.m.

WEDNESDAY, JANUARY 16

Morning Session, 9:00 a.m.

Jung Hotel

G. H. Cole, Presiding

Training Courses for Metermen	Harold W. Kelley, REA
Discussion	Henry M. Alford, REA
Training Programs for Utilities	H. R. Hill Westinghouse Electric Corp. Pittsburgh, Pennsylvania
Discussion	F. E. Heinemann, REA

WEDNESDAY, JANUARY 16

Afternoon Session, 2:00 p.m.

Jung Hotel

R. P. Stokely, Presiding

An Approach to Long Range System Planning . . .	Harry Dewar Patterson & Dewar Engineers Decatur, Georgia
Discussion	T. H. Hafer Corn Belt Electric Cooperative, Inc. Bloomington, Illinois
Discussion	James R. McCalman, REA
Discussion	E. L. Florreich, REA
Discussion	Harry R. Smith, REA

THURSDAY, JANUARY 17

Morning Session, 9:00 a.m.

Jung Hotel

G. L. Woodworth, Presiding

Exploratory System Designs at Higher KWH Levels..	T. D. Essig, REA and Harry Thiesfeld, REA
Discussion	Virgil Herriott Sioux Valley Empire Electric Assn., Inc. Colman, South Dakota
Discussion	Harold J. Christ Raymond H. Reed & Co. Columbus, Nebraska
Discussion	E. A. Loetterle, REA
Recent Changes in Line Design	James M. McCutchen, REA
Discussion	J. N. Thompson, REA
Discussion	John P. Hewitt, REA
Discussion	James H. Phillips, REA

THURSDAY, JANUARY 17

Afternoon Session, 1:30 p.m.*

(Joint Session with Operations Field Representatives)

Field Trip to New Orleans Public Service Co.
3700 Tulane Avenue

Safety and Job Training Demonstration . . . . . . New Orleans Public Service Company

I. Testing Rubber Safety Protective Equipment

II. Discussion of Frequency of Testing

III. Storage and Care of Hot Line Equipment

IV. Demonstration of Hot Line Tool Work

V. Question and Answer Period

The above program has been arranged and planned by Arthur J. Naquin, Safety Counsellor, and D. E. Therrell, General Superintendent, Electric Distribution Division, New Orleans Public Service Company.

Presentation will be made by Ivan Puritan, Electric Research Engineer, New Orleans Public Service Company.

*Take Tulane Avenue street car outbound to 3700 block (about a 10 minute ride). Program will start promptly at 1:30 p.m.

FRIDAY, JANUARY 18

Morning Session, 8:30 a.m.

(Joint Session with Operations Field Representatives)

Jung Hotel

E. E. Warner, Presiding

Planning for Business Security . . . . R. G. Zook, Moderator

A Panel Presentation by --

Robert D. Partridge, REA

John H. Rixse, Jr., REA

Edward F. Wilson, REA

Closing Remarks . . . . R. G. Zook

Conference will adjourn at 12:30 p.m.

NOTES

TOWARDS BETTER SERVICE RELIABILITY

By L. B. Crann
Systems Protection Engineer
Electric Engineering Division

For Presentation at the 1957 Technical
Conference for REA Field Engineers
New Orleans, Louisiana, January 14 - 18, 1957

REA

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

TOWARDS BETTER SERVICE RELIABILITY

INTRODUCTION

In the early days of REA the novelty of having electric lights in rural areas was great enough that the user tolerated and even accepted service interruptions as a normal condition. As electricity has been put to more and more uses, however, the user has become increasingly dependent upon continuous service and correspondingly has become less tolerant of any outage.

In some cases, outages mean only that the user is inconvenienced; in other cases, however, untimely and lengthy outages may lead to a financial loss which the user can ill afford. When service reliability is poor the user will look to other sources of power. These may be poor substitutes in our eyes, but to the user they have the all important advantage of being reliable. That this loss of business can affect the financial stability of a system seems evident.

Frequent or lengthy outages invariably lead to member dissatisfaction. Unfavorable comparisons are bound to be drawn between rural and urban service if the rural service is poor. Under these conditions, a public relations problem can develop which soon may get out of control if corrective measures are not taken promptly.

Obviously, then, frequent or lengthy outages no longer can be viewed with complacency. A higher degree of service reliability is required by the rural dweller and for the good of all he should get it.

It is the purpose of this report to discuss and evaluate measures which can be taken to improve service reliability on rural distribution systems. While the report stresses the importance of service reliability it should be recognized that this is only one part of a larger picture. In practice economic considerations have a large influence on system design and may prevent the adoption of measures which normally would be desirable for improved service reliability.

SUMMARY

Hazards to service vary too widely throughout the country for REA to suggest a service reliability standard which would be practical for all borrowers. By keeping records of hours outage per consumer per year the existing degree of service reliability can be determined. With this information, a standard or a goal for improvement can be adopted.

Good operating and maintenance practices plus hot line work seem to be essential for good service reliability. The adoption of a long-range plan should be very helpful in obtaining system designs which lead towards better service reliability.

Reliable service to the distribution system requires either a short radial transmission line or preferably a transmission network or loop. The substations should be relatively small in size so that fewer consumers are affected by a source outage. For this and other reasons, expansion of the system by installing additional substations rather than by increasing the capacity of existing facilities is desirable.

With respect to the substation transformers, single-phase units with a spare afford the best insurance against prolonged outages due to transformer failure provided that the spare is adequately maintained. Under some conditions, nearly equal service can be had with three-phase transformers and a mobile spare.

Relative to the distribution system, several technical difficulties will have to be overcome before a distribution network or loop is feasible. In any event, it appears that a high degree of service continuity can be obtained with the existing design of radial feeders. To attain this objective, it seems likely that many systems will be expanded at the present distribution voltage rather than by conversion to a higher voltage level. This will lead to a greater number of relatively small substations and to shorter distribution feeders, both of which are very desirable in reducing the number of consumer-outages. In this respect, studies of a typical 7.2/12.5 KV system indicated that a service continuity standard of one to two consumer hour outages per consumer per year required that no consumer be further than 10 to 15 miles from the substation.

Present sectionalizing techniques seem very satisfactory from the viewpoint of service continuity and only minor improvements appear possible. The use of more than 3 or 4 reclosers in series will not reduce greatly the number of consumer outages. However, additional sectionalizing devices, including disconnect switches and hot line clamps, are desirable, since these should be very useful in locating faults, reducing outage time, and localizing outages.

On important feeders, the use of a static wire or overhead neutral for lightning protection occasionally may be justified in areas where severe lightning damage is experienced. Similarly, on important feeders, a heavier grade of construction than normally used sometimes may be justified in areas subject to severe ice or wind storms. In this respect, studies show that the most damage to the line during these storms is caused by trees. Widening of the right-of-way, removal of "danger" trees, and brush control appear to be the most important actions which can be taken in wooded areas.

Finally, a disaster or emergency plan should be prepared and measures taken to make it effective.

CONCLUSIONS

For the foreseeable future, it appears that rural distribution systems will continue to be operated radially. Improved service reliability will result from the following, listed in their approximate order of importance:

1. Good maintenance and operating practices
2. Wide rights-of-way
3. Hot line work
4. Reliable sources
5. Short distribution feeders
6. Relatively small substations
7. Use of emergency feeders
8. Improved sectionalizing practices
9. Heavier construction on selected lines

A STANDARD FOR SERVICE RELIABILITY

Before considering a standard for service reliability, some way of measuring it must be agreed upon. The most widely used measurement of service reliability is the hours outage per consumer per year. This is determined as follows:

$$\text{Hrs. Outage/Cons./Yr.} = \frac{\text{Yearly Sum of Consumer-hour-outages}}{\text{Total No. of consumers}}$$

Where Consumer-hour-outages = Consumers affected x hrs. outage

Hazards to service vary too widely throughout the country for REA to suggest a service reliability standard which would be practical for all borrowers. Some idea of the range may be gained from one electric company's standard - one hour outage per consumer per year for urban users and two hours outage per consumer per year for rural users. Based on past studies this results in a maximum outage time for any individual consumer of from three to six hours for average years.

Within limits the degree of service reliability to be rendered is a policy decision based upon the needs and desires of the members. Answers to the following questions should help in arriving at this decision:

1. What is the present degree of service reliability in terms of:

    a. Average hours outage per consumer per year.
    b. Maximum outage time per year for any consumer.

2. Is the present service inadequate as indicated by:

    a. Numerous member complaints.
    b. Poor public relations.
    c. Use of other energy sources such as LP gas.
    d. Widespread use of standby equipment by members.

3. How does service reliability compare with the rural service of other electric utilities in area?

4. What maximum outage time can be tolerated without hardship to members by:

   a. Major farm equipment used in area.
   b. Residential loads.
   c. Large power loads.

5. What estimated service reliability standard will hold the outage time below the hardship level for any member?

6. What is the estimated cost of meeting this service standard?

The adopted standard should be considered a goal towards which steady progress can be made. The standard should be subject to periodic review so that it may be changed if conditions so require. Long-range system planning should help materially in attaining the desired level of service reliability.

Recommended Action

It is recommended that each borrower:

1. Set up outage records for each substation feeder or area.

2. Analyze this outage data after a year and adopt a service reliability standard, preferably in terms of hours outage per consumer per year. This standard should be adequate to satisfy consumer needs.

3. Analyze outage data for each feeder or area annually to determine where immediate remedial measures are needed. The overall system service reliability index should show a downward trend through the years until the standard is reached.

COST CONSIDERATIONS

An improvement in service reliability is going to cost money but probably not as much as might be expected at first thought. Usually the initial and the most rewarding step will be an improvement in operating and maintenance practices. This improvement requires essentially the will and desire to better existing practices. The cost of improved practices generally will be relatively small.

In wooded areas, widening of the rights-of-way will be most effective in improving service reliability. The cost of doing this may be kept within reason and a marked improvement in reliability may be obtained if

the widening is selective and gradual. The most important feeders should have the widest rights-of-way and be taken care of first. In the usual case, these rights-of-way will represent only a small fraction of the total rights-of-way on the system. Hence, maximum service reliability benefits from wide rights-of-way may be obtained readily at a comparatively low cost.

System design changes for improved service reliability need not be made until load growth requires system changes. The adoption of a long-range plan will be very effective in correlating the needs for service reliability with the development of the system. The additional cost attributable to improved service reliability under these conditions generally should be within reason.

All things considered, the cost of improved service reliability should not be excessive nor should it be great enough to affect the financial position of any borrower. This assumes, of course, restraint and good common sense on the part of management.

ELEMENTS OF THE PROBLEM

The service reliability index has three components:

1. Number of outages
2. Number of consumers affected by each outage
3. Duration of each outage

An improvement in service reliability will result when any of these components is reduced.

REDUCING THE NUMBER OF OUTAGES

Assuming uniform conditions, the number of outages on a system is related to the:

1. Total mileage of line
2. Exposure to natural hazards such as sleet and lightning
3. Exposure to man
4. Operating and maintenance practices
5. Design and construction practices

These variables may cause wide differences in the number of outages experienced by systems located throughout the country. Some idea of the magnitude may be obtained from outage data on an Eastern rural system

which shows 10 to 15 sustained outages per hundred miles per year. As compared to this, a reliable transmission line in the same area experienced outages of one-tenth of this number.

Of the above listed variables, the latter two may be controlled to some extent and will be considered in more detail.

Operating Practices (Planned Outages)

Usually the cause for an excessive number of planned outages is that the line crews are not trained to work the line hot. The solution is evident - adequate hot line equipment and more and better training.

Maintenance Practices

The urgency for good maintenance cannot be stressed too highly in any discussion of service reliability. Good maintenance generally will do more for service reliability than any other action which can be taken.

Outage records are a very necessary part of a good maintenance program. Outage record forms similar to those in REA Bulletin 161-1R1 are recommended for use. If kept faithfully, these records will reveal the feeders with poorer than average service continuity and indicate what and where maintenance is needed.

Relative to some maintenance details - trees can account for as much as 40 percent of all outages in wooded areas. Even more disastrous are the lengthy outages and widespread damage caused by trees during wind and sleet storms. Obviously, this maintenance item is a must for systems operating in wooded areas.

Automatic circuit reclosers inherently require more frequent maintenance than other line components. For service reliability purposes, they should get it.

Notwithstanding the importance of the above, poles, conductors and other components must not be neglected. To repeat - nothing will be more effective for improved service reliability than a good maintenance program.

It is recognized that cost considerations may limit the amount of maintenance which can be done. Records can be used to find out where urgent maintenance is required. To maintain service continuity at a high level, however, the system components which affect the most consumers or possibly the most revenue hours, should not be allowed to become

statistics in outage reports. The maintenance budget, therefore, should allot proportionately greater sums to the more important feeders and their rights-of-way, important line components, etc.

Design and Construction Practices

All design and construction practices influence the number of outages to some extent. However, some of these practices are fixed by service conditions and economics and offer little opportunity for change. Of the practices which can be modified the following are considered of sufficient promise to warrant further study:

1. Rights-of-Way
2. Grade of Construction
3. Shielding against lightning

Rights-of-Way

In wooded areas, wide rights-of-way should be most effective in reducing the number of outages. The extent to which a right-of-way should be widened depends somewhat on the species and height of the trees. Past experience should indicate the width which results in essentially trouble-free operation. Since it will seldom be practical to widen the entire right-of-way, priority should be given to the feeders which serve the most members and the most important loads, starting at the substation and working out. For optimum results, the right-of-way should be the same width between sectionalizing points.

Grade of Construction

As compared to the 10 to 15 sustained faults per 100 miles per year found on 12.5 KV distribution systems, studies show fault rates of approximately one-tenth this figure on many transmission systems. This suggests that the fault rate can be reduced by using heavier construction. However, further consideration shows that the superior performance of the transmission line is greatly influenced by:

1. Rights-of-way not subject to traffic hazards.
2. Wider rights-of-way.
3. Improved lightning protection because of high insulation level, static wires, etc.
4. Absence of distribution line equipment.

Therefore, a substantial reduction in the number of faults would not be expected if the grade of construction were increased. However, in areas where severe ice and wind storms are expected, heavy construction should

reduce the extent of the damage. In these areas, then, a heavier grade of construction can be justified for service reliability purposes even though the total number of faults may not be reduced greatly. (This assumes wide rights-of-way and good tree trimming practices so that tree damage will also be minimized).

Again, it should be recognized that all lines are not of equal importance. Therefore, main feeders affecting large numbers of consumers or important loads should receive priority. In most cases, cost considerations will not permit a similar grade of construction for the less important lines.

Shielding against Lightning

Placing the neutral on the top of the pole will shield the phase conductors and may possibly reduce the number of outages due to lightning. However, the low insulation level and relatively close conductor spacing of distribution lines require short spans and low ground resistance for the prevention of line flashover. These conditions are seldom found on rural systems. Also, in most cases, high costs limit the extent to which span lengths can be reduced and ground resistance lowered.

In areas of high lightning intensity, a static wire or an overhead neutral on all feeders for the first half mile from a substation is considered good practice for the protection of substations. The extension of the static wire or overhead neutral beyond this distance may be justified occasionally on very important feeders for service continuity purposes.

REDUCING THE NUMBER OF CONSUMER-OUTAGES

The foregoing has been concerned solely with reducing the number of outages. Another approach to improved service reliability is to reduce the number of consumers affected by an outage. This can be done by improved system design and sectionalizing practices.

Distribution System Design

Assuming uniform conditions, the probability of a fault is the same on any part of the system. On any feeder, then, the number of faults should be directly proportional to the feeder length. For example, a 20 mile feeder should average twice as many faults as a 10 mile feeder. The consumer-outages on a feeder will be proportional to the number of consumers, C, on the feeder times the length of the feeder, D, or Consumer-outages = D x C.

For the feeder shown in Figure 1A the consumer-outages are proportional to DxC.

If the feeder is split in two and served from both ends, the total number of consumer outages, due to faults on the feeder, will be halved. This is shown in Figure 1B.

This example has been over-simplified for illustrative purposes. In practice, conditions will not be uniform for the alternative designs shown. For example, the design of Figure 1A would require heavier conductor and more multi-phase line. Most likely, there would be greater transmission line exposure in Figure 1B. These would tend to work in favor of the single source design and reduce the improvement to something less than the two to one advantage shown. Despite this, studies of typical systems have demonstrated that service reliability can be improved substantially by reducing distribution line feeder length.

To realize a service reliability standard of 1 to 2 consumer-hours outage per consumer per year, studies of a typical system indicated that no consumer should be more than 10 to 15 circuit miles from the substation. Fortunately, in many cases load growth and system development are leading to shorter distribution feeders and additional substations. In those cases where load growth is met by increasing substation and feeder capacity, feeders will not be appreciably shortened and service reliability will not be improved. If service reliability is not adequate it is recommended that alternate plans of system development leading to shorter feeders and additional substations be considered even though these plans may be more costly.

Effect of Sectionalizing on Consumer-Outages

Can service reliability be improved by adding a large number of reclosers or other sectionalizing devices on a radial feeder? Assuming uniform conditions, mathematical studies indicate that the use of more than 3 or 4 reclosers in series has little effect on the number of consumer outages. The improvement is shown in Figure 2 and tabulated below using one recloser as the base for comparative purposes:

Table II

No. of Reclosers	% Consumer-Outages
1	100
2	75
3	67.5
4	62.5
5	60
10	55

Other studies have been made to determine the benefits gained by installing sectionalizing devices on taps. The importance of a tap is related to its length and the number of consumers who will be without power in the event of a fault on the tap. Mathematically, the importance of any tap can be expressed as follows:

Relative Consumer-outages = D x C
where D = total line mileage of tap.
C = total number of consumers affected by a fault on tap.

This equation says several things. A fault in a sectionalized tap affects only those consumers on the tap and the overall effect on consumer-outages is small. On the other hand, if the tap is not protected, a fault on it will affect not only its consumers but all those on the main feeder with a high influence on service reliability. By sectionalizing taps, therefore, substantial benefits can be realized in overall service reliability.

But not all taps can be sectionalized because of cost considerations and here the equation tells us where the most benefits can be gained. A short tap which causes a substation recloser to open may be more important than a longer tap which causes a recloser more distant from the source to open. Comparing the DxC product of the two taps shows which has the most effect on consumer-outages and shows where reclosers and other sectionalizing devices can be most effectively used.

It is possible to make a mathematical study of the effect of sectionalizing on service reliability with respect to the entire system. In practice, however, this should seldom be justified.

REDUCING THE OUTAGE TIME

While system design and sectionalizing practices have a large influence on the number of consumer-outages, the actual time a consumer is without power depends entirely on the time it takes to restore service. Multiplying the number of consumer-outages by the average restoration or outage time and dividing this by the consumers affected gives the true measure of service reliability-consumer hours outage per consumer.

The average time it takes to restore service following a sustained fault appears to be between two and three hours on most systems. The factors entering into this outage time are:

1. Elapsed time before outage is reported.
2. Travel time.
3. Fault location time.
4. Repair time.

Anything which can be done to reduce these times will improve service reliability.

Elapsed Time Before Outage is Reported

The time it takes to report an outage varies from several minutes to several days depending largely on the availability of telephone service, the importance of the load and the number of consumers affected. The elapsed time will be the least when a large number of consumers are affected and probably longest when only one is out of service. Future developments should bring more telephones in rural areas; also there is always the possibility that a low cost outage monitor will be developed. Meanwhile, members should be reminded periodically of the necessity for reporting outages without delay and given telephone numbers which can be reached at any time for reporting outages.

Travel Time

Two-way radio cuts travel time during regular working hours, by making it possible to dispatch the nearest service crew. For emergencies, outside of regular hours, it seems logical to divide the system into sub-areas with a serviceman available for calls at any time in that area. Except for the smaller systems, stationing all service equipment at a central location each night does not seem to be the best practice for reducing outage time.

Fault Location Time

Fault location time depends largely on whether the cause of the fault is obvious or hidden. In both cases, the location time varies directly with the number of sectionalizing points which can be opened. Therefore, the more sectionalizing devices installed the easier will it be to isolate the fault. These devices may be reclosers, sectionalizers, fuses, disconnect switches, hot line clamps, etc. A curve showing this relation is given in Figure 3.

The curve of Figure 2 showed that the number of consumer-outages would not be reduced materially by using more than 3 or 4 reclosers in series. On the other hand, Figure 3 shows that the fault location time will be reduced directly by adding sectionalizing devices in series. In using these curves, it should be recognized that automatic circuit reclosers have high annual costs and may, in themselves, constitute a serious hazard to personnel and to service. Therefore, the minimum number required for reducing consumer outages should be used as shown in Figure 2. On the other hand, more disconnect switches, automatic sectionalizers, fuse cutouts, load pick-up switches etc. should be used to facilitate location of hidden faults. The exact number used continues to be a matter of engineering judgment based on past experience.

Repair Time

Repair time for the usual fault can be kept to a minimum by:

1. Thorough training of service personnel.
2. Adequately equipping service trucks.
3. Stocking adequate spare parts and equipment at strategic locations.

4. Immediate dispatching of additional men and equipment where needed.
5. Strategic location of service men.
6. An effective disaster plan.

<u>In no case, should unsafe practices be used in order to speed up repair time!</u>

On many systems the service reliability record is greatly influenced by a few lengthy outages caused by source failure, or by widespread storm damage. Every system should have an emergency plan which provides for a course of action in the event of source or substation transformer failure, excessive storm damage, etc. If a study shows that lengthy outages will be unavoidable under some circumstances, additional tie feeders or heavier construction should be considered to lessen the hazard.

SOURCE OUTAGES

Source outages have a disastrous effect on service reliability. A source consisting of a long radial feeder generally will be least dependable. In addition, if it also has the following characteristics, service reliability will suffer:

1. Long in length.
2. Unshielded from lightning.
3. Relatively low voltage (2.4 - 22 KV)

Where all of these conditions exist, an alternate feeder or a new, more reliable source eventually will be needed.

In the development of the system, service reliability of alternate sources must be considered. Where several sources exist, economic studies should include the cost of providing the desired degree of service reliability from the various sources in a comparison of exploratory plans.

SUBSTATION OUTAGES

While the failure of a substation transformer is a comparatively rare occurrence, the possibility must be considered in view of the large number of consumers affected by a failure. Single-phase transformers with a spare offer the best insurance against a prolonged outage from transformer failure. The available spare may serve several substations if it can be readily transported when needed.

Three-phase transformers can offer nearly equal service reliability if the following conditions prevail:

1. All substations are essentially the same size.
2. There is a mobile spare substation.
3. Roads to the substation are passable in all weather.
4. Bridges are able to withstand the weight of the mobile equipment
   or
   Tie feeders are available which can carry the load without excessive voltage drop if any substation fails.

These limitations on the use of three-phase transformers are important. If they can be met, system development with three-phase transformers will lead to reasonably short feeders and relatively small substations. Both of these lead to improved service reliability.

USE OF 14.4/24.9 KV AS A DISTRIBUTION VOLTAGE

A number of systems have constructed distribution lines at 14.4/24.9 KV in sparsely settled areas where 7.2/12.5 KV lines were not economically feasible. Many of these 14.4/24.9 KV lines are long - some extend well over 100 miles from the substation. It appears that a poorer standard of service reliability will have to be accepted primarily because of the feeder length, increased travel time and increased fault location time inherent under these conditions. Efficient operating and maintenance practices will be all the more important for these systems if outage time is to be held to a minimum.

Some 7.2/12.5 KV lines have been considered for conversion to 14.4/24.9 KV as a means of coping with load growth. Under certain conditions, this conversion can become economically attractive; however, the savings should be weighed against the effect on service reliability.

Conversion of a 7.2/12.5 KV system to 14.4/24.9 KV generally takes the following pattern:

1. Feeder length and conductor size remain approximately the same.
2. Number of substations remain unchanged.
3. Substation sizes tend to get larger.

None of these tend to improve service reliability.

On the other hand, expansion of the system at the present voltage level can lead to:

1. More substations of relatively small size.
2. Shorter distribution feeders.

These tend toward better service reliability. For improved service reliability, therefore, it seems likely that many systems will continue to utilize existing distribution voltage levels as they expand.

WILL LOOP FEEDERS PREVENT CONSUMER OUTAGES?

Tie feeders between substation areas can be very effective in preventing outages during routine maintenance operations and in reducing outage time during emergencies. A word of caution on their use is in order.

1. The tie feeders must be operated open under normal conditions, particularly when they connect different sources.

2. When they are tied together during emergencies, care must be taken that the voltage does not drop low enough to cause motor damage anywhere on the system.

Suggestions have been made to connect the tie feeders together at all times and operate the system as a "loop" for improved reliability. However, before this can be done several technical difficulties must be overcome:

1. Following the loss of one source, the alternate feeder may have to carry a substantial emergency load. This may result in an excessive voltage drop and damage to consumers' motors unless the feeders are designed with the necessary capacity to operate under emergency conditions. It should be recognized that the voltage drop for uniform conditions varies directly with the square of the distance on a radial feeder. Therefore, even at moderate loading at the time of the fault, say 50% capacity, dangerously low voltages could result on parts of the system.

2. The automatic circuit recloser, as presently made, will not work properly either with the two feeders tied together or under radial conditions following the loss of one feeder. In Figure 4, for a fault at "N", fault current from Source "X" will open the 50 ampere recloser "A", but which 35 ampere recloser, "B" or "C", will open in response to fault current from Source "Y"?

   To sectionalize this system, oil circuit breakers controlled by at least two sets of relays would be required. Whether the benefits gained will be worth this investment seems questionable.

3. Voltage regulators in the tie circuit will have to be modified to permit parallel operation and reverse current feed.

4. The power supplier may object to the distribution system acting as a tie between the transmission systems. There is a possibility of power flow through the distribution system which would require special metering. If the transmission lines are part of separate systems a phase angle difference may exist which will make the tie impossible, unless special measures are taken.

5. Voltage drop studies and sectionalizing studies will be more complex and probably require Network Analyzer Studies.

If the alternate feeders are operated radially with a transfer switch to pick up load automatically following an outage, the first three difficulties will still be experienced until normal conditions are restored. Therefore, the use of tie feeders for the present must be restricted to emergency use to pick up as much load as possible by manual switching. Under these conditions a somewhat lower than normal voltage probably can be tolerated; however, care must be taken that the voltage does not drop to a value which would cause damage to motors and other equipment.

* * *

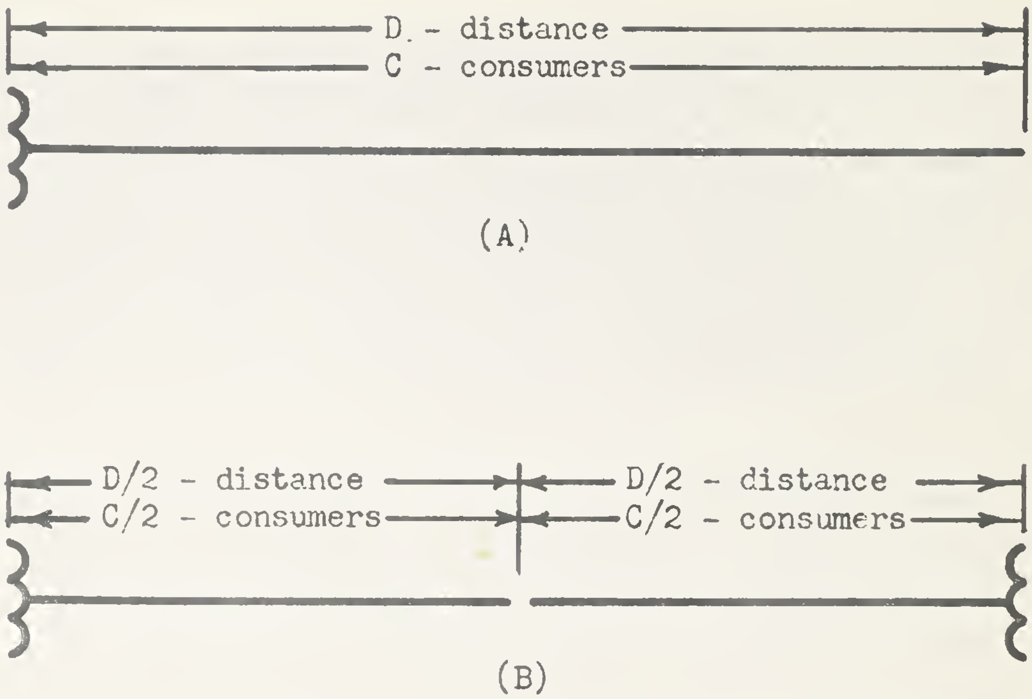

Fig. 1. Effect of feeder length on consumer outages.

A. Cons. Outages = D x C

B. Cons. Outages $\frac{DC}{4} + \frac{DC}{4} = \frac{DC}{2}$

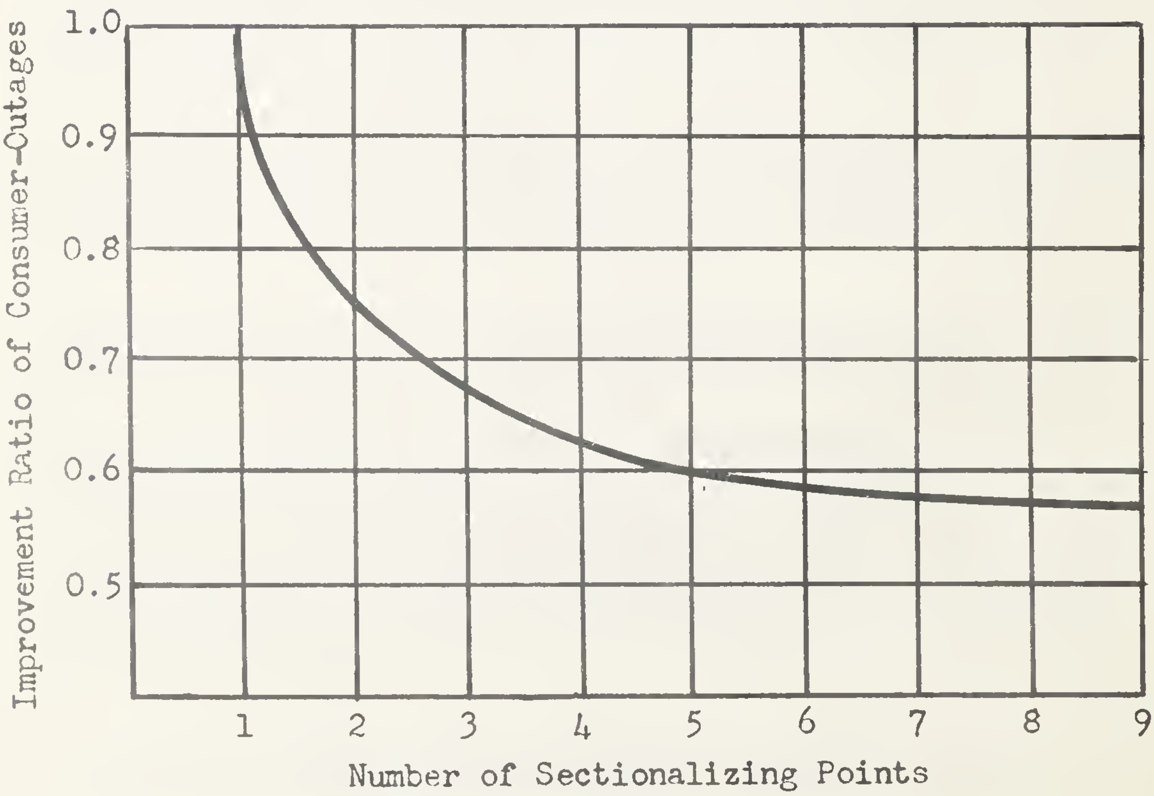

Fig. 2. Effect of equally spaced sectionalizing devices in reducing number of consumer-outages assuming uniform conditions.

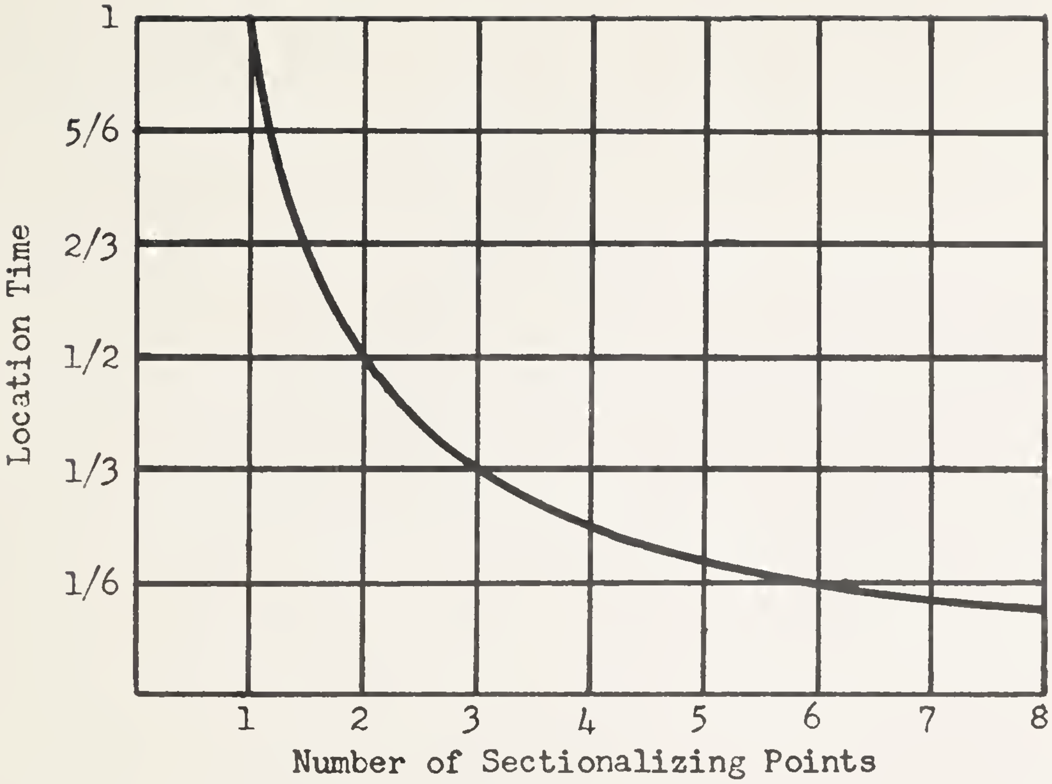

Fig. 3. Effect of equally spaced sectionalizing points in reducing time to locate faults. Travel time to sectionalizing point is not included.

Fig. 4. Circuit showing use of present reclosers on loop feeders. To isolate the fault at "N", reclosers "A" and "B" should open. In practice, fault current from source "Y" may cause recloser "C" rather than "B" to open.

POSSIBILITIES OF NUCLEAR REACTORS ON REA COOPERATIVES

By Wade M. Edmunds
Special Assistant - Nuclear Power Projects
Office of Assistant Administrator - Electric

For Presentation at the 1957 Technical
Conference for REA Field Engineers,
New Orleans, Louisiana, January 14 - 18, 1957

REA

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

POSSIBILITIES OF NUCLEAR REACTORS ON REA COOPERATIVES

Wade M. Edmunds

BRIEF SUMMARY OF THEORY

Physics and chemistry did not used to be such difficult subjects until Einstein proposed that mass and energy were interchangeable - then things began to happen. Instead of being satisfied with the atom as a basis for material, some scientists got inside the nucleus and found many things going on - at high speeds. The energy which we talk about develops from breaking up that nucleus so it is a little more accurate to talk of nuclear energy than of atomic energy.

It is now assumed that all atoms are built up from three fundamental particles, the proton, neutron, and electron. The number of protons and the number of electrons in the nucleus of an atom are equal and of opposite charge. The neutron has no charge and therefore more easily enters the nucleus of another atom.

To start a reaction, a neutron strikes the nucleus of a U-235 atom. This causes the atom to split or fission into two fragments which in turn eject more neutrons - an average of 2.5 neutrons per fission. This surplus of neutrons is the basis for the chain reaction.

Whereas chemical reactions, such as ordinary combustion, involve a rearrangement of the outer electron shells of atoms, nuclear reactions involve a rearrangement of the protons and neutrons within the nuclei of atoms. Energy changes in nuclear reactions are of the order of millions of electron volts compared with energies of a few electron volts for chemical reactions.

In order to describe a nuclear reaction, it might be helpful to give a nuclear equation for the process in question. Suppose, for example, we would like to know what happens when Boron absorbs neutrons. This is a common occurrence because Boron is used for control rods in reactors. The equation may be written:

$${}_5B^{10} + {}_0n^1 \rightarrow {}_2He^4 + {}_3Li^7$$

The reaction started out with Boron plus a neutron and converted into two new elements, Helium and Lithium.

Here is what happens when Uranium is struck with a neutron:

$${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{92}U^{236}$$
$$\searrow$$
$${}_{92}U^{236} \rightarrow F^1 + F^2 + 2.5\,{}_0n^1$$

You will note that instead of forming new elements, the uranium nucleus split into two fragments with an accompanying release of a large amount of energy.

Fertile materials play a very important role in reactors, particularly those used for power generation because of the economy derived from producing new fuel. Uranium 238 and Thorium 232 are the most common fertile materials. They are not themselves fissionable but can be converted.

In 1940 at Berkeley, it was discovered that U 238 absorbs slow neutrons to produce U 239 which in turn becomes Pu 239 (Plutonium).

Similarly, Th 232 is transformed into U 233.

Note that although the two fissionable isotopes U 233 and Pu 239 are derived from fairly abundant Th 232 and U 238, each conversion process requires a source of neutrons which at present must come from U 235; one fissionable material must be consumed to produce the others. However, it can be shown that it is economical to do that.

The underlying principle for any theory of nuclear chain reactors is the conservation or balance of neutrons. The general equation representing this balance may be written:

$$\text{Production-Leakage-Absorption} = \frac{dn}{dt}$$

where $\frac{dn}{dt}$ is the time rate of change of the neutron density.

If the reactor is operating at a steady state, $\frac{dn}{dt}$ will be zero, and

$$\text{Production} = \text{leakage} + \text{absorption.}$$

The above is very briefly the elementary diffusion theory. Neutrons diffuse through matter as a result of being scattered by atomic nuclei. A typical neutron trajectory would be a zigzag pattern of straight line elements of varying lengths joining the points of collision. Simply stated, two things happen to neutrons after leaving the source - they leak out (disappear) or they are absorbed by the atoms of other materials. It is only when neutrons are absorbed and fission that they do useful work; more efficient neutron absorption in fertile material, such as U 238, represents the major effort toward development of economical power.

Neutrons are also absorbed in structural materials but do no useful work. Consequently, the selection of structural materials is determined as far as possible by their low neutron absorbing characteristic.

The time involved in changes occurring within the core of a critical reactor is so short that it is always under automatic control - the human hand and eye are not quick enough. For example, the excess of neutrons from one generation over the preceding one is δk and the increase for "n" neutrons is $n\delta k$. If l^* is the effective time between succeeding generations,

$$\frac{dn}{dt} = \frac{\delta kn}{l^*}$$

which integrated gives

$$n = n_o e^{(\delta k/l^*)t}$$

for:

$l^* = .001$ sec.
$\delta k = .003$ (reactivity change)
$t = 3$ sec.

the power level "n" = e^9
"n" = 8103

which means that the power level has increased by a factor of 8103 since the power output is proportioned to the number of neutrons in the core in any given time interval.

MATERIALS

Materials are required in power reactors for a number of purposes: fuel, fuel diluent and cladding, fertile material to form new fuel, moderators in thermal reactors, coolants, control elements, structural materials, and neutron and temperature-sensing devices. The central problem is heat removal.

The criteria on which materials are selected might include the following items:

a. Cost
b. Availability
c. Neutron absorption and scattering cross sections
d. Corrosion resistance
e. Heat transfer
f. Resistance to radioactive damage and to dimensional changes
g. Reactivity buildup
h. Physical properties, such as ductility, tensile strength, and creep resistance at high temperatures
i. Mechanical properties, workability, ease of welding
j. Chemical properties

The neutron properties limit the practical materials, regardless of cost, to only a few elements. Some of these are given below:

	Heterogeneous		Homogeneous	
	Thermal	Fast	Thermal	Fast
Fuel	U 235, U 233	Pu 239	U 235, U 233	Pu 239
Fertile	U 238, Th	U 238	U 238, Th	U 238
Moderator	H2O, D2O, C	None	D2O	None
Coolant	H2O, D2O, Na	Na	D2O	Bi, Pb, Fused Salts
Cladding and Structural	Al, Zr, SS	SS	SS, Zr	SS
Control	B, Cd, Hf	B	None	None

The number of neutrons emitted per fission and the net numbers of neutrons available for use after the nonfission absorption is considered are important. These are illustrated in the table below:

Isotope	Average Neutrons per Fission	Ratio Non-Fission, Fission	Net Neutrons Per Fission
U 233	2.50	-	-
U 235	2.50	0.184	2.12
Pu 239	3.00	.42	2.11

Fuel

For power reactors, the fuel will be chosen in combination with the fertile material in order that as much new fuel will be produced as possible. There are several reasons for this: (1) the fuel more nearly maintains its original reactivity, (2) reloading is less frequent, and (3) the cost of the fuel is reduced drastically.

The U 235 in natural U makes this an excellent fuel from a cost standpoint. Its drawback is that slight enrichment is required for use in H2O and Na-moderated thermal reactors. When fuel grade Pu (high Pu 240 content) becomes available from operation of a reactor, this can be used for part or all of the slight enrichment required. This places a considerable premium on natural U, as the U 235 present in natural U is the cheapest fissionable material. However, only a part of this U 235 can be used. The use of U 233 and Th may prove to be economical because it may prove possible to obtain a higher conversion ratio in a thermal reactor than with U 235. The U 233 formed in Th and the Pu formed in U can be completely separated by chemical processes.

For fast reactors Pu and U 238 will be used because of their high conversion ratio of 1.5 or greater.

Cladding Materials

The choice of a cladding material is dependent upon its corrosion resistance to the coolant and its ability to cover or protect the fuel. Other requirements are reasonable cost, high thermal conductivity, good tensile strength and good creep resistance, high ductility, ease of forming by rolling, extrusion, etc., and the ability to be easily removed or dissolved in the chemical separations plant.

While several materials are available, the only practical ones are Al, Zr, and stainless steel. The material selected will depend upon the choice of coolant. If H2O or D2O are to be used, either Al or Zr would be used; for Na, the choice would be Zr or SS. Al can be used up to 230C, Zr up to 350C, and SS up to 650C.

Structural Materials

In general, Al, Zr and stainless steel structural materials will be used in a reactor when these same materials are used as the fuel cladding materials. In homogeneous reactors, stainless steel, Zr, Ti or Ta will be used for most solutions. For liquid metals special stainless steel or alloys will be required.

For a large homogeneous reactor, a solution of UO2 SO4 in D2O could be used as fuel, moderator and coolant with stainless steel as the material of construction. The use of enriched fuel with Zr separating the reactor core from the blanket may be developed to give separate core and breeding blankets.

Shielding Materials

Shields are usually broken up into two parts. First, there is the "thermal" shield; the purpose of this is to reduce the neutron level as well as the gamma-ray level to levels about 10^8 per cm^2 per second. Since many fast neutrons reach the shield without being moderated or slowed down, the shield should contain a large amount of light hydrogen to slow down these neutrons. The shield should also absorb thermal neutrons rapidly without emitting additional gamma rays. At the same time, it is desired to absorb as many gamma rays as possible. Therefore, a dense shield is desired.

The materials which have been used are hydrogenous materials such as water combined with boron and iron to absorb the thermal neutrons. Iron absorbs neutrons satisfactorily, but at the same time gamma rays are emitted. Boron strongly absorbs neutrons without the emission of gamma rays. So the thermal shield consists of alternate layers of water and steel with a thin layer of boron carbide, held in aluminum, placed over the inner steel layer, or boron steel (2%) may be used. When energy of the neutron and gamma rays is absorbed, the thermal shield is heated so that it must be cooled. This is simple for a water-iron shield, as cooling water can be pumped through the shield.

Outside the thermal shield is the biological shield which reduces the neutron and gamma rays to a tolerable level for humans. As mass and neutron absorption only are needed, ordinary concrete or concrete with high specific gravity aggregate such as barytes or limonite may be used. Thirteen inches of ordinary concrete reduces the gamma-ray intensity roughly by a factor of 10.

Moderators

The measure of moderating ability is the effect of slowing-down power on neutrons. This means that the neutrons must have both a high probability of hitting and must also lose a large fraction of their energy at each collision. H2O, D2O, Be, BeO and C are all usable moderators. D2O, Be, and BeO are all expensive, and C requires large volumes. BeO is cheaper than Be and also has a higher density of Be atoms; it will probably be used only for special purposes, such as research reactors like the MTR.

The decision between H2O, D2O and C must be on a complete cost analysis of the various reactor types.

Organic moderated reactors using hydro-carbon diphenyl are being actively studied and give promise of many advantages.

In homogeneous reactors, D2O is the only practical combination coolant-moderator for a UO2SO4 solution.

Coolants

The choice of coolant is also of primary importance and it ties in with the decision as to which type of reactor system is chosen. The obvious coolants are CO_2, helium, H2O, D2O, sodium and bismuth.

Helium has the objections of high pumping charges and the necessity for recirculation. A large external heat transfer surface would be required to cool the

helium due to low heat transfer rates. Because of the pumping charges gases have not been considered extensively for power reactors if power is to be produced through a steam cycle. The use of gases combined with gas turbines may, however, prove attractive.

Ordinary water is particularly attractive because of its low cost; however, in power reactors where high temperatures operation is necessary, water cooling, both H2O and D2O, becomes less desirable because of high pressures. Water also becomes radioactive and emits very strong gamma rays of short life on leaving the reactor. Impurities, such as sodium in the water, become radioactive and the system must be completely leakproof. The water decomposes into hydrogen and oxygen in the radiation field and this gaseous mixture must be diluted or recombined to prevent explosive mixtures. Light water is a very efficient moderator, but hydrogen has a rather high neutron absorption.

H2O as a moderator and coolant cannot be used with natural U and it is necessary to use graphite or D2O moderators or slight enrichment. The cost of slight enrichment must be balanced against the high neutron absorption, high pressures, and tight lattices required for H2O reactors. The main objection to H2O and D2O is the fact that water is very reactive and, therefore, corrosive material.

Organic coolants have been studied, but while they undergo rapid decomposition under the irradiation in power reactors, they offer many advantages. The use of D2O as a coolant and moderator is advantageous from a neutron viewpoint and because natural U can be used in a D2O cooled and moderated reactor. The cost of D2O requires that the volume of the system be a minimum and that losses be held low. D2O system must be leakproof, decomposed gases must be recombined, and great care must be taken in handling it.

The use of Na as a reactor coolant is extremely attractive for high temperature operation because of the low vapor pressure (no pressure vessel), low corrosive properties, and high heat transfer rates. The entire system must be entirely leakproof because of the danger of reaction between Na and air or water. The handling of Na is difficult because of its melting point, 97 C, and radioactivity after neutron exposure. All Na surfaces must be blanketed with inert gases to prevent fires. All portions of the equipment must be provided with heaters to prevent freezing, and a purification system must be provided to remove Na2O and other impurities.

The use of Bi has been under study at Brookhaven National Laboratory. In this case the U is dissolved in the Bi; fused salts look promising as extractants for the fission products in a continuous recycling process. The additional advantages of uranium-bismuth solution fuels are stability to radiation as well as temperatures.

Control Elements

For thermal reactors, B, Cd or Hf are used and the cladding materials are the same as that used on the fuel.

REACTOR TYPES AND APPLICATION

There are two general categories of reactors - heterogeneous and homogeneous. These two terms merely describe reactors on the basis of the relative arrangement of fuel and moderator.

In a heterogeneous reactor, the fuel is distributed in a fairly definite geometrical pattern or lattice within the mass of the moderator.

A homogeneous reactor, on the other hand, is one in which the fuel is more or less evenly dispersed throughout the moderator. A uniform solution of solid fuel and liquid moderator is a common example.

Types of reactors are further classified according to some outstanding characteristic, such as:

1. Pressurized Water
2. Boiling Water
3. Swimming Pool
4. Heavy Water
5. Graphite
6. Sodium Graphite
7. Liquid Metal Cooled
8. Liquid Fuel
9. Fast Breeder

The above are still only broad classifications with possibilities of about 1,000 different types being designed. With such a broad field, it is going to be extremely difficult to concentrate on a few of what might be called the "best designs." There is a real evaluation problem ahead which is essential to undertake before economical manufacturing can begin.

Two proposals have been submitted by REA borrowers to AEC which give promise of resulting in construction:

1. Boiling Water Reactor - Minnesota 70

   The major characteristics of this reactor are as follows:

   a. Heterogeneous, closed cycle, natural circulation

   b. Fuel - natural uranium spiked with enriched U 235

   c. Cladding - zirconium

   d. Capacity - 58 MW heat
      22 MW net electric

   e. Reactor operating pressure - 900 psig

   f. Separately fired superheater

   g. Steam to turbine - 600 psig
      Temp. 825° F

   Figure 1 shows a diagram of the reactor portion of the plant.

General Description of Boiling Water Reactor

The reactor plant consists of the reactor, primary heat exchanger, and auxiliary equipment as indicated in Figure 1. The entire plant is enclosed in a concrete block

about 16 feet wide, 60 feet long, and 50 feet deep, mostly below ground level.

Steam at 900 psig and 533° F is produced within the reactor vessel by water entering from below and passing over the fuel plates of the core. It then flows to the tube side of the heat exchanger shown at the upper right of Figure 1. There it condenses and returns by gravity to the reactor vessel. Circulation within the reactor vessel is produced by natural convection.

The primary heat exchanger performs as a boiler drum to produce steam at a working pressure of 650 psig. Steam flows to a separately fired superheater and thence to the turbine at 600 psig and 825° F.

Reactor steam pressure is regulated by the control rods inserted into the core through the bottom of the reactor vessel. The movement of these rods is automatically controlled and except in an emergency, the movement is in very small increments. A decrease in reactor pressure causes the control rods to be moved out of the core thereby increasing the heat output and an increase in pressure causes them to be re-inserted.

The reactor and all primary loop components are sealed in a welded steel shell buried in concrete. In the event of a rupture in the primary loop, water and steam will fill the containment shell. In the event of an accident whereby fission products are released, all valves located in lines leading outside the containment shell will be automatically closed by monitoring devices. In the event the control rods become stuck, the reactor can be shut down automatically by injecting a boric acid solution into the reactor vessel.

The handling of fuel elements involved in the removal and replacement in the reactor core is very specialized work because of the radiation hazard. Very special tools and precautions are necessary so it is expected that such work will be contracted at first.

Routine operations of the reactor system can probably be handled by two operators per shift. Suitable alarm and interlocking systems will afford sufficient protection and the regular turbine plant operators will be available if needed.

General Description of Aqueous Homogeneous Reactor - Michigan 46

The names of the component parts of the reactor system are about the same as for the boiling water type - reactor, heat exchanger and auxiliary equipment. However, the reactor and auxiliary equipment are quite different in design.

The reactor vessel, as you will see in Figure 2, is a stainless steel sphere 5 feet in diameter and about 3 inches thick, which contains the fuel dissolved in heavy water, D20. The fuel is one of the uranium salts, uranyl sulfate, with an enrichment of U 235. Since this particular design is the one region type, no conversion or breeding takes place.

Steam at 600 psi is produced in the heat exchanger by forced circulation of the heated fuel solution through the tubes and back to the reactor vessel. Steam then flows to a separately fired superheater and is delivered to the turbine at 530 psia.

A pressurizer is connected to the outlet from the reactor. Its function is to pressurize the system to an average pressure of 1900 psi.

The control method is very simple. Because of the large negative temperature coefficient the homogeneous reactor may be operated entirely on the concentration of the fuel solution and the temperature coefficient. This means that to start up, sufficient enriched fuel is pumped into the reactor vessel so that it will go critical. As the flux and temperature rise, the power will level off at the predetermined temperature and the entire plant will then operate on the power demand. More power output lowers the temperature which increases the reactivity, flux, and power until a new balance is reached.

The components of the primary loop are arranged inside a containment vessel which is 15 feet in diameter and 32 feet 6 inches high. A partial radiation shield of high density concrete aggregate is located around the reactor vessel and this is supplemented with about 8 feet of concrete in the biological shield.

Fuel make up is easily accomplished during normal operation of the reactor and no shut down is necessary. A pulsa feeder type pump is used to force the concentrated fuel solution into the primary loop. During full load operation the pump would need to work less than one hour per day.

During operation, fission products are formed in the fuel which in turn absorb neutrons to detract from the effectiveness of the fuel to generate heat. Such products are generally called poisons and must be removed. The removal of poisons and corrosion in a homogeneous reactor can be a continuous process by by-passing a small amount of the fuel solution through chemical processing equipment. The chemical processing plant is contained in a vapor tight stainless steel lined cell with structural strength sufficient to contain the resultant pressure developed from any major failure of components in the chemical processing system.

General Description of Sodium Cooled Heavy Water Moderated Reactor - Alaska 8

This proposal differs from the other two in that there is more work on research and development needed which has been set up as the first phase and will be completed before much additional work is done.

It will be a sodium cooled, heavy water moderated reactor rated at 10,000 kw electric. The novel feature of the design is the use of sodium coolant with D2O moderation.

The fuel elements will be 3/4" metallic U alloy rods clad in stainless steel or zirconium. Steam will be at 850 psi and 850° F.

Evaluation of Reactors

The evaluation of the several types of reactors to determine which will be the most economical is being undertaken in order that manufacturers can concentrate on at least some limited form of mass production of the components. Naturally every designer is fully convinced that his type is the best, but the following fundamentals should be taken into account:

Turbo-Generator Plant Cost and Net Station Efficiency as Affected by Steam Temperatures

1. Turbo-generator estimated plant costs vary from $125/kw for 400° F steam to $97/kw using 1000° F steam which makes the higher temperature

desirable from a capital investment standpoint. Such steam should be generated directly in the reactor and not obtained through a superheater fired by one of the fossil fuels which rarely pays for itself. A superheater of that type is installed for the purpose of avoiding the use of a non-standard turbine.

2. Net station efficiency varies with the steam temperatures - from 24% at 400° F steam to 35% for 1000° F steam. To obtain the higher efficiency, the most promising design used liquid sodium as a coolant at temperatures of 900° F to 1000° F.

The attached curves, Figure 6, give estimated values of Net Station Efficiency and Turbo-generator Plant Cost compared to Steam Temperatures.

CAPITAL COSTS

Capital costs and operating costs are very much in the estimating stage. No nuclear plants have been completed or are in operation so that no actual construction or operating costs are available.

The following table indicates the estimated capital costs of 17 different types of reactors. An average of these would be about $275/kw which does not mean much in view of the spread of costs.

Estimated Capital Costs of Nuclear Power Plants

	Reactor Type	Power MW-Elec.	Capital Cost $/kw*
1.	H20 mod. and cooled	60	792
2.	D20 mod. and cooled	234	352
3.	H20 mod. and cooled	180	280
4.	D20 mod., H20 cooled	100	365
5.	H20 mod. and cooled	200	183
6.	Graph. mod., H20 cooled	700	249
7.	H20 mod. and cooled	134	257
8.	H20 mod. and cooled	250**	220
9.	Boiling H20	300	226
10.	Boiling H20	180	250
11.	Na-Graph.	150	291
12.	Na-Graph.	150	243
13.	Na-Graph.	75	364
14.	Fast Breeder	173	269
15.	Fast Breeder, Na cooled	100	540
16.	Aq. Homogeneous	100	256
17.	Aq. Homogeneous	180	240

*Costs do not include fuel inventories

**Includes 110,000 kw conventional superheating capacity

PRODUCTION COSTS

The main problem is in estimating (a) how long a reactor will last, (b) operating and maintenance costs, and (c) net fuel cost after adding charges due to fuel inventories, fuel burn-up and fuel reprocessing and then subtracting the value of new fissionable material in the reactor.

At the present time, it is not possible to utilize completely a charge of fuel in a reactor. It must be removed some time prior to that time because of irradiation damage to fuel elements, to buildup of fission products and to depletion of fissionable material.

A long burn-up time of fuel should be sought after which it is reprocessed. In spite of present high cost of reprocessing, fuel so obtained is lower in cost than if bought new. After reprocessing, the fuel metal is returned to a fabrication plant where new elements are made for reinsertion in the reactor.

The initial cost of the fuel charges is an expensive item. It is not economical to maintain a large stock pile of fuel elements outside a reactor because of their high cost and for the same reason, unreasonably large quantities of fuel should not be tied up inside the reactor. It is therefore necessary to have as high a specific power as possible (kw/kg of fuel).

Average inventory is charged on 1.5 loadings since there would be, on the average, a half loading in the external processing plants including fuel elements awaiting charging.

The question of how long a reactor will last is one for which no definite answer is available. Most estimates use about 20 years.

A rough estimate for costs would be 8 mills/kwh for production and 5 mills/kwh for fixed charges.

INSURANCE

Definite information is not now available on insurance but it is expected that some discussion can be held during the conference.

EDUCATION AND TRAINING IN NUCLEAR ENGINEERING

The Research and Development Subcommittee of the Joint Committee on Atomic Energy held hearings in April and May 1956 on the shortage of scientific and engineering manpower. There is of course a shortage.

The report stressed the deterioration of mathematics instruction in high schools.

AEC is active in educational work as evidenced by operating the School of Nuclear Science and Engineering at the Argonne National Laboratory, and the Oak Ridge School of Reactor Technology at the Oak Ridge National Laboratory.

It also sponsors training conferences for educators and schools, and loans natural uranium and neutron sources to schools for use in experimental reactors.

However, the demand for scientists and engineers by the industry is far greater than is available. Even with the interest shown by scientists and engineers to enter atomic energy work, there have not yet been enough training resources to provide them with the specialized skills to adapt their basic background.

The total needs for scientists and engineers in all atomic energy programs in 1956 are about 16,000, more than half of which should be engineers. The number needed will soon rise to 41,000, and by 1975 it is estimated that 63,000 will be wanted. These figures represent about half the number of graduates in those fields.

In addition to the two schools operated by the AEC at Argonne and at Oak Ridge, many colleges and universities offer courses in nuclear engineering. These have been cataloged by the Nuclear Engineering Division of the American Institute of Chemical Engineers. The publication is available, for 50¢, at the following address:

American Institute of Chemical
Engineers
25 West 45th Street
New York 36, New York

Indicative of the courses offered are tne following:

Johns Hopkins University
School of Engineering
Baltimore, Maryland

Title of course - Reactor Engineering

Credit hours - 2 credit hours per semester for two semesters

Catalogue description - A survey course of the field of reactor engineering with particular attention to the peace time uses of nuclear power. Topics presented are a brief historical review, basic aspects and principles of reactor design and operation, various types and uses of reactors, various engineering problems and considerations of economy of nuclear power.

Prerequisites - elementary differential equations, Atomic Physics 17.3-4. (Atomic Physics was waived as a prerequisite in some cases.)

University of Maryland
College Park, Maryland

Title of course - Nuclear Reactor Engineering

Credit hours - 6 semester hours

Catalogue description - Introduction to the engineering problems of the design, construction and operation of typical nuclear reactors, including general design, nuclear reactor theory, materials of construction, heat transfer, control, etc. Emphasis is toward commercial nuclear reactors.

Prerequisites - Permission of instructor

North Carolina State College
Raleigh, North Carolina

Title of course - Introduction to Nuclear Engineering

Credit hours - 2 semester hours

Catalogue description - A survey of the engineering applications of nuclear energy. The principles and practices of isotope separation, production of plutonium, and nuclear reactor operation are studied along with the peace-time uses of products and by-products of nuclear reactors. Major engineering problems involved in each phase of the study are defined and the special methods of approach indicated

Prerequisite - Phys. 410 (Nuclear Physics)

Title of course - Radiation Hazard and Protection

Credit hours - 3 semester hours

Catalogue description - The hazards from external exposure to ionizing radiation are evaluated. The dosages resulting from the ingestion of radioactive materials are computed. The precautionary methods used in radioactive work are presented. Selected biological effects of ionizing radiation are studied.

Prerequisite - Phys. 410 (Nuclear Physics)

Title of course - Nuclear Reactor Laboratory

Credit hours - 1 semester hour

Catalogue description - Observations on and measurements on the behavior of the nuclear reactor, and correlation with reactor theory. Experiments with apparatus involving the motion and detection of neutrons. Foil measurements of neutron flux. Irradiations in the reactor of samples to produce isotopes.

Co-requisite - Phys. 530

Pennsylvania State University
State College, Pennsylvania

Title of course - Nuclear Engineering

Credit hours - 3:3:0

Catalogue description - Slowing down and diffusion of neutrons; reactor physics and computation of critical masses.

Prerequisites - Physics 237, Math. 84

Title of course - Nuclear Engineering

Credit hours - 3:3:0

Catalogue description - Reactor kinetics; heat transfer and properties of materials under radiation; power reactors; flux measurements and kinetic experiments with the reactor.

Prerequisites - Physics 237, Math. 84

TRAINING OPERATORS, FOR EXAMPLE AT SHIPPINGPORT, PENNSYLVANIA

Except where recent college graduates are used and where individuals with specialized training, e.g., radio-chemists, are required, all personnel probably can be obtained from within the company.

In addition to on-the-job training, all technical and some non-technical men are given practical training in reactor-station operation to provide background for their own jobs and to instill an appreciation of the hazards involved. Each technical man also receives theoretical nuclear training and all personnel receive general training in health physics and security.

Most training is provided at Naval Reactor Facility at Arco, Idaho. About 50 men will have trained for an average of 4 months.

MAJOR FACTORS TO BE WORKED OUT

1. High temperature nuclear fuels must be developed, capable of operating over a wider temperature range and of burning longer.

2. The cost of reactor materials, e.g., Zr, Be, and D2O must be greatly reduced.

3. New construction materials capable of withstanding severe corrosion and extreme temperature range must be developed.

4. More efficient moderators needed.

5. Smaller and lighter reactor shields.

6. Low cost fuel recovery processing.

7. Training sufficient personnel to advance the program more rapidly (adult education of practicing engineers in industry offers relief).

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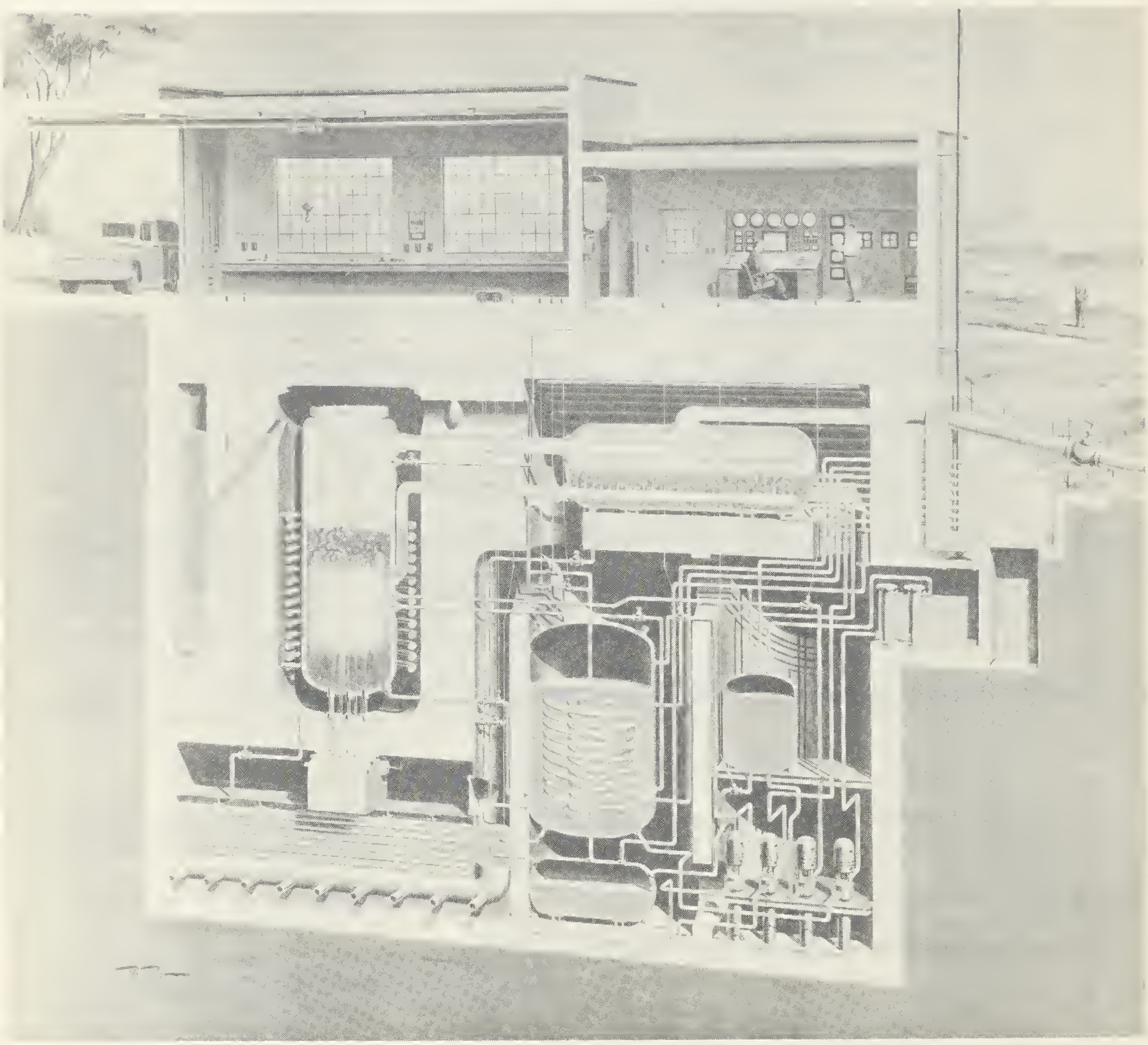

Fig. 1. Boiling Water Reactor

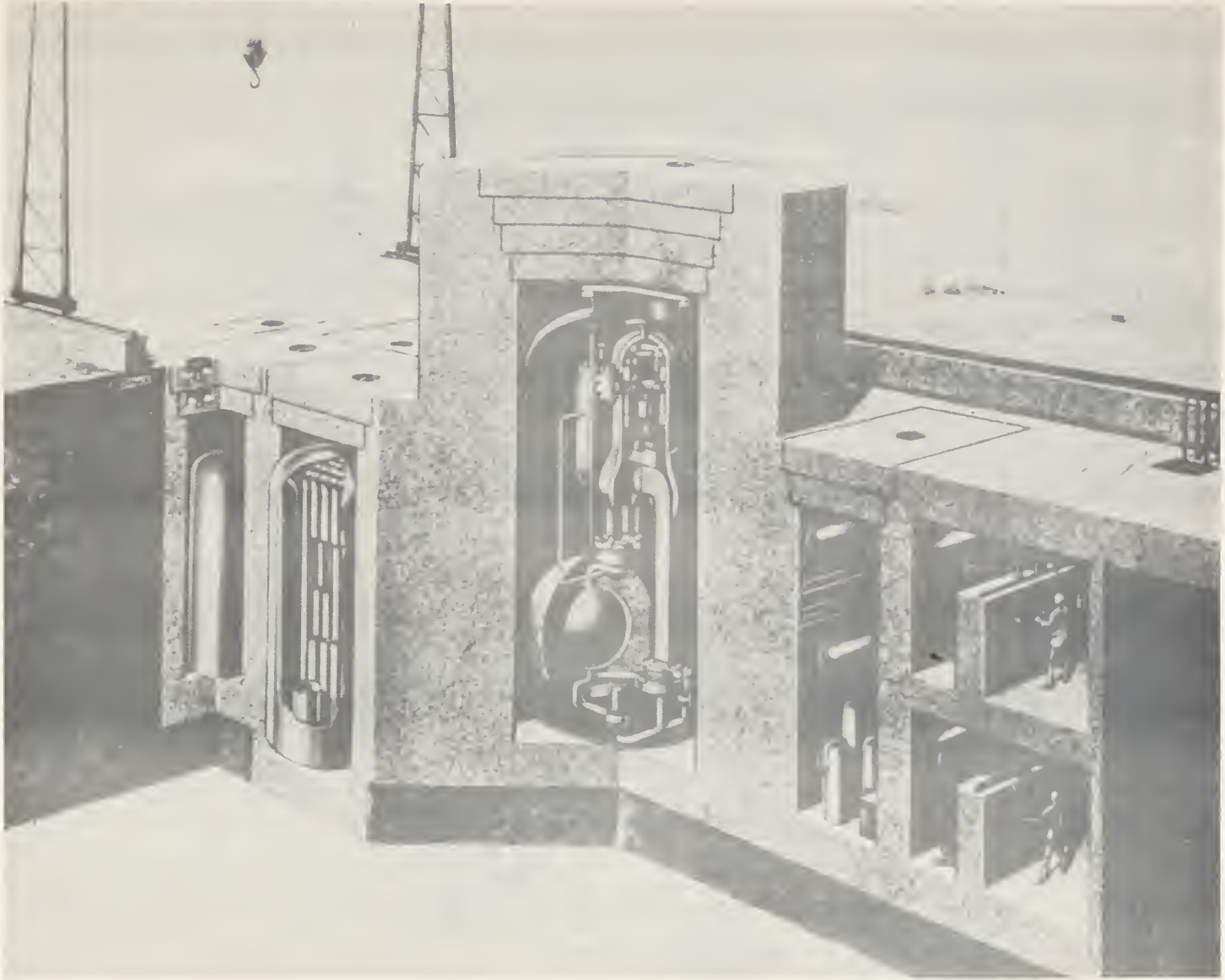

Fig. 2. Aqueous Homogeneous Reactor

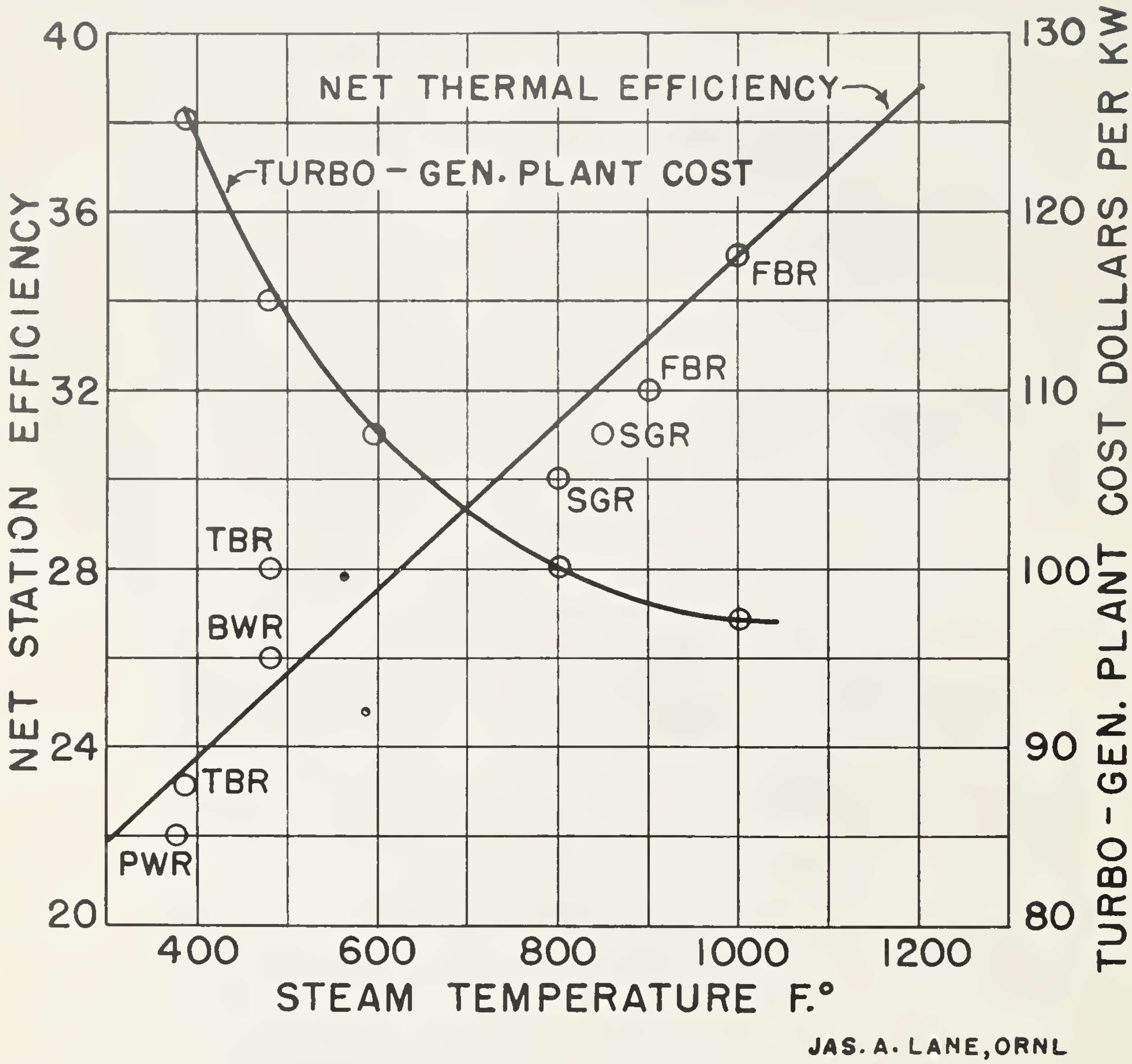

Fig. 3. Characteristics of Nuclear Steam Turbogenerator Plants

OPERATIONS AND MAINTENANCE PRACTICES

By U. J. Gajan, General Manager
Southwest Louisiana Electric
Membership Corporation
Lafayette, Louisiana

For Presentation at the 1957 Technical
Conference for REA Field Engineers,
New Orleans, Louisiana, January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

OPERATIONS AND MAINTENANCE PRACTICES

U. J. Gajan

INTRODUCTION

The first and most important function of Management is organization. Providing the tools and technics of planning, organizing, directing, co-ordinating and controlling in order to accomplish the objective -- To provide abundant, dependable electric service at rates which will encourage the most widespread use, consistent with sound business principles.

We have gradually emerged from a period of construction, serving rural establishments, into a period of backboning our system to provide capacity and dependable service to our member-consumers. Let us never forget that management faces a real challenge and the end results are reflected in our "Operations and Maintenance Practices."

The concept of "Operations and Maintenance Practices" could be divided into two important aspects, that are not always in parallel. The first, based on theory, would generally cover the "ideal". Second, the practical aspects, which are generally patterned after the "ideal", but controlled by and adapted to local conditions.

Probably, we all lean towards the practical aspect because of its versatility. A well-planned program can be made flexible, and adaptable to changes as necessity and circumstances dictate.

Therefore, it is quite evident -- that quality service with rates that encourage the most widespread use of electricity and provides a safe return on the invested dollar is desirable.

Because I am familiar with our own system, I find it advisable to prepare my paper, based upon our own operations and what we are doing to carry out the objectives of Southwest Louisiana Electric Membership Corporation. The topic is so broad that only certain phases can be covered in the time available.

DISPATCHING, OUTAGE REPORTING AND RECORDS

Approximately eight years ago a new plan was placed in operation. This plan called for selecting three skilled persons, capable of performing:

1. Office work.

2. Learning the physical system of the Cooperative to receive trouble calls and make outage reports.

3. Learn the dispatching practices and supervise servicemen after office hours.

This method eliminated the old system of calling the manager or the servicemen at their homes at night. The day and night telephone numbers were identical and facilitated the consumer-members' reporting trouble.

Consequently, the flow of office work continues uninterrupted 24 hours a day, 365 days a year. With this system we save the equivalent of two full-time office employees, and realize lower insurance rates.

These men have been assigned full responsibility and have been trained to recognize the difference between important and unimportant calls. Their training also incorporated a wide latitude of independence in making the necessary decision and mapping the proper course of action when a situation presented itself.

We operate with 31 different points of connection which includes metering stations and substations. A schematic diagram has been prepared of each station, showing in detail the geographical layout of the station, with respect to feeder lines and branch lines. This mapping system has improved efficiency, by making available to the dispatcher, information that can be pin-pointed -- corrected and relayed to the serviceman for his immediate action, thereby restoring service with the minimum of time lost. Results -- more economy and better consumer relations.

The proper recording of Outage Reports is a matter of great importance. When properly summarized, it plays a major role in giving us a background, not readily detectable, in planning and carrying out a course of corrective and preventative maintenance. (Figure 2 shows a sheet prepared for our use.) This gives us complete information in regards to destination of each truck -- time checked out -- time leaving job and time checked in. It also provides the name of the party reporting the trouble -- the time called in -- the time given to service truck and also the time when mission has been completed. The causes are also recorded. This provides us with a complete report on the servicemen's activity, expediting clearance of trouble, resulting in more efficiency. You will note from (Figure 1) that fuse sizes are clearly specified, which eliminates improper fusing on branch lines. Fuses are replaced based upon the record of the Dispatcher.

Each month, a summary is made of all information gathered on the Outage Report Sheet. From this factual information, we can plan and carry through the necessary steps to correct the problem. (Figure 3) summarizes each fuse interruption on a station by station basis. As an example, (Figure 3) indicates LCA-1 Ext. operated twice during the month of January. The remaining seven months show no operation on this particular extension. You will also note other information on these reports that forms the basis for instituting corrective measures. Only a report of this type can give true values and a complete picture of what takes place over a given period of time.

OCR MAINTENANCE RECORDS AND COST

A complete system was established for inspecting and maintaining the OCR. The records which we maintain on our OCR's, covers location, date installed, size, serial number, phase location and number of operations or counter readings. (See Figure 5 OCR Installation Report.) Monthly field checks are made on all OCR's located at strategic points such as, substations and other lines carrying sizeable loads. Monthly OCR Field Report (See Figure 4) is the report presently in use. It serves as an accounting record for OCR's on an individual station basis. This report is invaluable, considering that it reflects not only the performance of the OCR, but also reflects unusual happenings on the system.

When OCR's are found operating too frequently, steps are taken to find the cause and make immediate corrections. It also serves as a guide to determine when the OCR's should be returned to the shop for servicing. Our shop is operated part-time and this employee is skilled to do numerous jobs. In the shop, the OCR is removed from the tank, checked, cleaned and oil changed. A complete record is maintained, (See Figure 6, OCR Test and Cost Record), showing serial number, type and size, opening sequence, counter check, multi-amp or battery check, oil test, acid test, insulation test, drying time, parts changed, material and labor cost. In most cases, repairs are minor and requires only routine checks and oil changes, involving only labor charges. A complete routine check requires less than one hour at a cost of $1.40 each. Minor repairs can also be made during this period of time while the oil is being filtered in our filter press. In the past four years, we have filtered and reused in excess of 3,000 gallons of oil. This is a real savings, considering the cost of oil at present market value. With this type of work — together with proper records, unnecessary checks and unnecessary repair work is eliminated.

POLE REPLACEMENT

All electric systems are faced with an urgent need for a comprehensive pole inspection and pole replacement plan. In 1954, utilizing our available records, we estimated that 30% of our poles had been in existence from 12 to 15 years. Our lines were constructed in eight large counties; therefore, the older poles are also scattered throughout the eight counties. This involved a major problem. How to do this at a reasonable cost and still accomplish our objective?

After much study, a plan was put into effect where the job of Right-of-Way clearing and pole inspecting be combined. This system has produced good results at very low cost. This combined work is done by two 3-men crews, covering the entire system, clearing trees and checking poles simultaneously. In addition to checking all strain poles, every fourth pole is completely inspected. If an unreasonable number is found bad in any one section, then all poles in that area are checked thoroughly.

In order to check a pole thoroughly, we found it necessary to dig around the base of the pole approximately 15 to 24 inches, checking for fungi growth or any other type of wood rot, then striking pole with a blunt instrument, in order to determine soundness. If questionable we run test with Increment Borer. Pole is then treated with solution of Penta-Preservative Concentrate (ten parts oil — one part concentrate) from a point starting about 24 inches above ground level, allowing solution to run slowly on outer surface of pole to below ground level. We then refill excavation, pouring remainder of oil directly on ground embankment. A small metal non-rust, marker approximately 1/2" x 1" is then nailed to the pole, indicating the year the pole was inspected. Records are only established on questionable poles still having some life expectancy. (See Figure 7, Pole Inspection Record.) This record is broken down into three categories, earmarked to be reinspected again in three -- five or ten years, dependent upon the condition of pole.

Our records reflect that approximately 50 poles per day can be inspected at a labor cost of $.68 per pole, including transportation. Pole inspection requires an estimated 88 to 110 working days. The preservative cost, $.12 per gallon, or a total cost of .80¢ per pole. Six thousand poles are treated annually at a cost of $720.00 for the preservative. Labor and transportation cost $4,080.00, or a total cost of $4,800.00. We have experienced in some areas that poles are more susceptible to rot than in others. During the month of December 1954, of 2,280 poles checked, 136 poles needed changing. This is a mortality rate of approximately 6%. These poles had an

average life of approximately 15 years. The average mortality rate over the past two years ran less than 2%. Figure 8 shows permanent records kept on pole replacement. This record is kept on a month-by-month basis and used to set up graphs, in an effort to establish trends in the future.

RIGHT-OF-WAY RECLEARING METHODS AND COST

Prior to combining our pole inspection and Right-of-Way reclearing, it was customary to cover our entire system within one year. This time has been extended by approximately four months or a total of 16 months to do the combined job. The Lengendary Tales that are so reminiscent of the South, regarding bayous, swamp lands, plantations adorned by ageless oaks and pecan trees are not legendary in our area. This area of Southwest Louisiana has a very small percentage of heavily wooded areas. Most trees are of the ornamental type to provide shade or bear fruit. Therefore, all of our reclearing is done by manpower requiring the use of saws, tree trimmers and brush hooks. This work is done by crews assigned to the area on a station basis. As the reclearing is completed on each respective station, the area is marked in red on a designated map showing date work was started and date completed.

Considering the scarcity of heavy timber, it was necessary that we deviate from a per unit basis and define the number of trees rather than the footage. (See Figure 9.) Under trees trimmed and cut is indicated large, medium or small. Spans of underbrush is indicated as heavy, medium or light. Figure 9 also indicates number of brush loads and hours of riding time. Small trees range from 2 inches to 4 inches in diameter, medium trees 4 inches to 12, and larger trees would be classified as 12 inches and above. Brush is classified as anything under 2 inches. Listed below is what we consider a good week's work.

Trees Trimmed			Trees Cut			Spans Underbrush	Brush Loads
L	M	S	L	M	S	M	
100	35	25	3	10	125	3	4

In order to realize the maximum production at the lowest possible cost, a 3 man Right-of-Way crew has been located in the town of Washington, approximately 26 miles from Lafayette. This crew takes care of the entire northern area of our system with the southern area being operated out of the Lafayette office. By decentralizing our Right-of-Way crew, an average of $450.00 per month has been realized in savings to the cooperative.

For the year ending December 31, 1955, reflected a total of $19,090.86 had been spent on transportation and right-of-way reclearing. This money was spent to maintain 3,797 miles of electric transmission and distribution lines, at a cost of $5.03 per mile.

ROUTINE LINE INSPECTIONS

Routine line inspections should be based on a carefully scheduled program, adapted to your own type of terrain and operations, and found to be adequate from experience. We find that routine line inspection falls into three categories:

1. Routine patrols to reveal incipient trouble.

2. Normal maintenance based on results of large area (long lines) inspection.

3. Emergency location and immediate repair of trouble.

All major feeder lines of Southwest Louisiana Electric Membership Corporation are inspected once each year. A Work To Be Done Schedule is compiled by the inspector and transferred to specific work orders for immediate field correction.

The system is divided into specific work areas, easily accessible to sub-warehouses, located at strategic points on the system. Field personnel stationed at these various locations are responsible for carrying out clean up requirements specifically requested on clean up work orders. Time sheets reflect maintenance progress for each respective date. Adequate maps carefully marking of special access roads and proper pole numbering proves to be very essential. Clean up sheets must properly and unmistakably tie into good mapping system. Maintenance of lines is largely a matter of effective planning and co-ordination.

Personnel stationed at various sub-warehouses have proven to be very effective in the overall operations and maintenance economy of this organization. Thousands of transportation miles and an untold number of man hours have been converted from unproductive riding time to productive hours worked each year.

In summary, distribution line patrol and maintenance, whether routine and normal, or in emergency, is a specialized field. It calls for organization, tools and equipment. As in all other phases, we are constantly bringing modern and more effective methods and equipment of our own design to meet specific conditions and problems.

VEHICLE MAINTENANCE AND COST

Transportation is a major item of expense to an electric utility. We must therefore utilize our equipment to obtain the maximum use and results at the lowest operating cost per unit.

When thinking of vehicle maintenance and cost, in its proper perspective, we must think of numerous and essential items such as labor, parts, tires, gasoline consumption, lost time because of breakdowns, and life expectancy of vehicles. When all of these various items of cost are totaled at the end of each month, and the total mileage of each truck pro-rated, these items reflect the true picture of cost — that is, cost per mile of operation. We are constantly faced with the problem of how to improve our transportation and lower cost, drawing upon our previous experience and records.

Many years ago we found it necessary to construct and operate our Mechanic Shop and all other related activities. Our shop is completely equipped, capable of doing any type of repair on any transportation unit. Our shop is operated by a Head Mechanic and a qualified and experienced helper. The shop opens at 7:00 a.m. each morning for the purpose of effecting any minor repairs or repairing flat tires. This avoids holding up any truck from leaving on schedule to accomplish a good day's work.

Over the many years of operating experience, we found that the appearance of the truck is very important to receive maximum value on trade-in. Therefore, a schedule has been arranged so that each truck is polished once every six weeks. Any dents or scratches on the trucks are straightened and painted on the week-end. Consequently, average trade-in value has been approximately $700.00 on trucks having 80,000 to 110,000 miles.

Each Saturday, a schedule of preventative maintenance is carried out. Each truck is given a complete inspection, with emphasis on minor repairs. During vacation periods, all utility beds and bodies are repaired and painted. The end results have been so effective that we have continued to use service bodies that have been in use for 13 years or longer. These bodies are still capable of performing service for another 7 to 10 years. Our cost of sanding and painting trucks is approximately $24.00 per unit, including labor and material.

All major repair jobs are also performed in this shop, which includes transmission and differential, rebuilding motor and any type welding necessary to carry through a good maintenance job.

Figure 12 shows a complete breakdown of the operating cost of each unit on a monthly basis. You will note that this particular analysis is for the month of May, reflecting an average operating cost of under 8¢ per mile.

Figure 10 shows a breakdown of items of material used on each truck. I am showing only one sheet in the essence of saving space. You will note that the records are substantially the same as that shown in Figure 12; however, this gives us the advantage of comparing parts on each individual truck on a month-by-month basis.

Figure 11 shows a complete analysis of our tire record. This record materially assists us in selecting the proper type tire for the proper use. A record such as this is our only means of determining the type of tire that renders the best service.

WAREHOUSING AND ISSUE OF MATERIALS

Many years ago, due to the large area covered by our Utility System, we began a planned program of decentralizing our operations. This decentralization has contributed to: first, better service; and second, economy in operations. We divided our area into four separate districts, namely, Lafayette, Kaplan, Washington, and Crowley, Louisiana. Lafayette being our largest district, we operate a fleet of seven trucks and five maintenance and construction units. In Washington, we operate two maintenance and construction trucks and one service truck. In Kaplan and Crowley, we operate a maintenance and construction truck and a service truck for each station.

Warehouses were constructed in each of these districts, resulting in better service to our consumers. Through decentralization of crews and warehouses, we save annually 46,980 miles of travel and $15,686.40 in labor and transportation cost. We maintain an inventory of $6,000.00 on material and supplies, and $3,000.00 in meters and transformers in each of our sub-warehouses. All material received into these warehouses are transported from our Lafayette warehouse, where we maintain an inventory of approximately $125,000.00 in material and supplies, and an additional inventory on meters and transformers amounting to approximately $100,000.00.

As we expanded and opened these branch warehouses, maintaining adequate records became a grave problem. Time required to keep the inventory records, on our old system, was doubled and even tripled. We then instituted the peg board system of a printed form, listing all material items and punched in order to fit on this peg board. In addition, we purchased a Burrough's Sensimatic Posting Machine, which relieves the warehouseman from making all posting by hand, eliminating possible errors. This method saved us approximately 15 days from the old system of charging out, posting and writing everything by hand. At the present time we are able to keep complete records, without delaying the work, with a staff of one warehouseman and one full-time assistant, and one part-time assistant.

To give us a double check, it was decided that the Warehouseman would fill out the tickets from a list of material left the previous night by the Crew Leaders. The stock clerk was to fill this order exactly the way it was listed. Should the Warehouseman list the wrong item, then the stock clerk would have issued this item and the inventory would not be affected. The Crew Leader knowing what items he asked for would realize this mistake when he checks his materials each morning and the error can be corrected.

Each morning, between 7:00 and 7:30 a.m., the material is charged out to each crew. Therefore, there is no delay in the crews leaving on schedule for their day's work. After all the trucks have left for the field, the salvage material which is left by their doors is segregated, counted, and a record is made of the salvaged items. These items are then placed into the bins provided. A complete listing is kept on ledger forms and are balanced and closed out at the end of each month. These monthly records give us a breakdown of the following:

1. Materials used for construction.
2. Materials used for maintenance.
3. Materials used for maintenance of transformers.
4. Materials used for maintenance of general property.
5. Materials used for maintenance and transportation expense.
6. Materials checked out to warehouses.
7. Materials sold.
8. Materials salvaged.
9. Materials received from vendors.
10. Materials returned from sales.
11. Balance on hand as to quantity, amounts, and unit price.

A physical inventory is taken at the Lafayette warehouse every six months. The three sub-warehouses are inventoried every three months. Our physical inventories agree close to our book quantities, reflecting our practices as being correct.

All materials and supplies and other items necessary in the operation and maintenance of our electric utility system are advertised for bids every three months. These requirements are based on the material used in the preceding six months divided by two. We then have a close estimate on how much material will be needed within the next three months. Our savings have been tremendous. For 1955, we checked our bid prices as against the last quantity quoted book price, and the amount of savings totaled in excess of $20,000.00. We purchased approximately $146,000.00; therefore, our net savings represented 13.6%.

In conjunction with materials and supplies records, we also keep records on auto parts, tires, tubes, gasoline and other equipment. We perform a physical inventory on these items monthly.

The gasoline is charged to individual trucks on a daily basis. Readings of the pump registering gasoline tank are taken daily and a record is kept on all gas consumed. This record has proven very efficient and our gasoline shortage does not exceed that percentage which is allowable for evaporation.

CONCLUSION

The key to good operations and maintenance practice is organization: First, determine your objective, then plan and direct accordingly. Integrate your people and activities according to their ability to get the job done. Always remember that cost is not always the determining factor. High operating and maintenance costs do not necessarily reflect bad management. And neither do low operating and maintenance costs always reflect good management. Therefore, it is quite evident -- that quality service with rates that encourage widespread use of electricity and provides a safe return on the invested dollar is desirable. We must constantly strive to gain new efficiency and economy and simultaneously provide the best service at the lowest possible cost.

STATION DIAGRAM

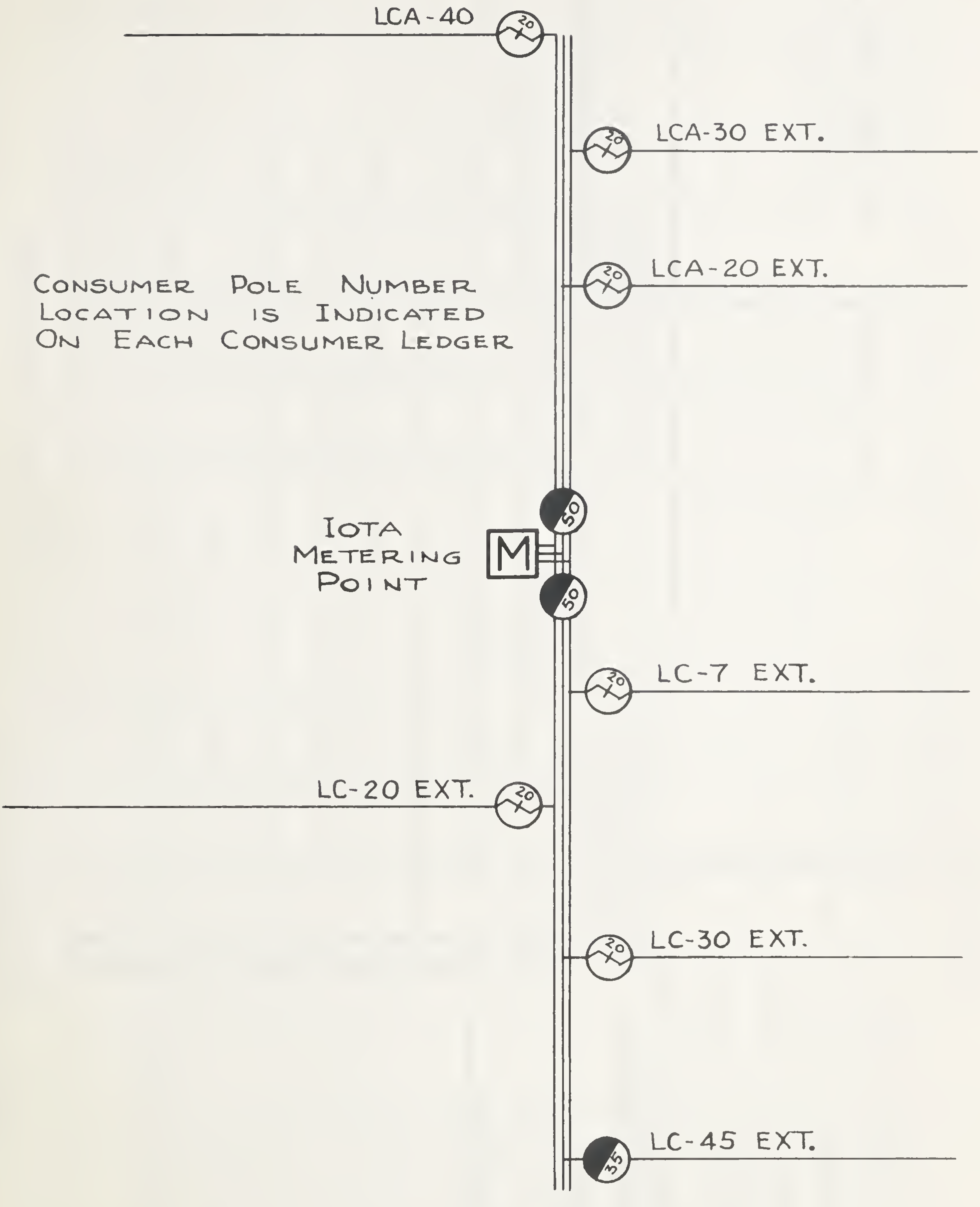

FIGURE 1

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION

Trouble Shooter ✓
Construction
Maintenance
Right of Way
Others

Name of Dispatcher	From	To
Thomas Harvey	8:00 a.m	5:00p.m

Date: 11-5-56
Name: Dallas Duhon
Truck No. 8

Time Schedule of Men

Destination:		Time Check Out	Time Leave Job	Time Check In	Name of party calling	Time called In	Time given Call	Time trouble cleared	Description of Trouble	Fuse Size
Lafayette Area	AM	7:30			John Doe	9:00	9.01	9.20	Fuse Out in House.	
	PM		4:30	5:00	LCA-25					
	AM									
	PM									
	AM									
	PM									
	AM									
	PM									
	AM									
	PM									

Figure 2 - Daily Outage Report Sheet

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

STATION: Iota

LOCATION	PHASE	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
LCA-1 Ext.		2	0	0	0	0	0	0	0				
LCG-2 Ext.		0	2	3	2	0	0	0	0				

Figure 3 - Operating Switch Summary

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

STATION: Morrow

Location	Size	Phase	Direction	Serial No.	Date and Counter Readings																			
Station	50H	C	North	1234	11-56 Jan	0000	11-56 Feb	0001	12-56 Mar	0002	12-56 Apr	0003	12-56 May	0008	12-56 Jun	0008	11-56 Jul	0010	11-56 Aug	0011	Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
-----					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec
					Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept	Oct	Nov	Dec

Fig. 4 - MONTHLY OCR FIELD REPORTS

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

LOCATION	DATE INSTALLED	OIL BREAKER SIZE	SERIAL NO.	PHASE LOCATION	NO. OF COUNTER OPERATION	REMARKS
LC-1	1-1-56	50-H	1234	c Ø North	0000	

Fig. No. 5 - OCR Installation Report

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

SERIAL NO.	TYPE & SIZE	OPENING SEQUENCE	COUNTER CHECK	MULTI AMP OR BATTERY	OIL TEST	ACID TEST	INSULATION TEST #1		INSULATION TEST #2		DRYING TIME	DATE	PARTS CHANGED	MATERIAL COST	LABOR COST	TOTAL COST
							READ	ALLOWABLE	READ	ALLOWABLE						
1234	50H	2+2	OK	OK	30KV	OK	6	12	6	12	16 hrs.	1-1-56	Coil	18.70	1.00	19.70

FIG. NO. 6 - OCR TEST AND COST REPORT

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

Pole No. LC-1 Date Installed 1938

Date Checked 11-5-56 Date Removed ____________

Make ACW Size 35-6

Type Treatment Penta Solution

Inspection To Be Made Again 11-59

Remarks After First Inspection ____________

____

Remarks After Second Inspection ____________

____

Figure 7 POLE INSPECTION RECORD

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

LOCATION	SIZE	MAKE	DATE INSTALLED	DATE REMOVED	REMARKS
LC-1	35-6	ACW	1938	11-5-56	Rotted at ground

Figure 8 POLE MORTALITY RATE MONTH November, 1956

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

NAME: Abby Noel

DATE FROM 10-1-56 TO 10-29-56

	Trees Trimmed			Trees Cut			Spans Underbrush			Brush Loads	Hours Riding	Location
DAY	L	M	S	L	M	S	H	M	L			
Monday	14	1				15				1	2	TB Line
Tuesday	18	3	1				2			2	1.5	TA Line
Wednesday	27	5	1			5				1	2	IB Line
Thursday	21	8				22	3			1	2	IB LINE
Friday				1	6	35	1				2	IB Line
Saturday												
TOTAL	80	17	2	1	6	77	6			5	9.5	
Monday												
Tuesday												
Wednesday												
Thursday												
Friday												
Saturday												
TOTAL												
Monday												
Tuesday												
Wednesday												
Thursday												
Friday												
Saturday												
TOTAL												

Day		NUMBER OF POLES INSPECTED						REMARKS
Monday		Mon.		Mon.		Mon.		
Tuesday		Tues.		Tues.		Tues.		
Wednesday		Wed.		Wed.		Wed.		
Thursday		Thur.		Thur.		Thur.		
Friday		Fri.		Fri.		Fri.		
Saturday		Sat.		Sat.		Sat.		
TOTAL								

Figure 9 - Right-of-Way Clearing & Pole Checking.

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION
Lafayette, Louisiana

PARTS USED AND REPAIRS MADE ON COMPANY VEHICLES
FOR THE MONTH OF MAY 1956

TRUCK NO.	ITEM & DESCRIPTION	UNITS	TOTAL
1	Misc.	$3.28	
	Casite	.60	
	Seal Beam	2.82	
	Dimmer Switch	.95	$7.65
2	Misc.	3.28	
	Casite	.60	
	Cartiridge	1.07	4.95
3	Misc.	3.28	
	Casite	.60	
	Cartiridge	1.07	
	Seal Beam	1.41	6.36
4	Pintle Hook	38.75	
	Bolt Assembly	1.00	
	Repair Boom	13.85	
	Misc.	3.28	
	Casite	.60	
	Cartridge	1.19	
	Flasher	.81	59.48
5	Misc.	3.27	
	Casite	.60	
	Cartridge	1.20	5.07
6	Misc.	3.27	3.27
7	Misc.	3.27	
	Rod	.15	3.42
8	Misc.	3.27	3.27
9	Misc.	3.27	
	Flat & Sheet Iron	1.25	
	Hub Bolts	2.25	
	Gears	7.14	
	Spacer, shaft, lock, gaskets	1.94	
	axle shaft	21.98	
	Shocks	7.92	
	Flange	3.12	
	S eals	2.21	
	Bearings & Spacer	11.46	

Figure 10 - Sheet 1 of 4

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION

REPORT ON JUNKED TIRES - MAY 1956

TICKET NO.	SERIAL NO.	PLY	TYPE	MAKE	SIZE	DATE INSTALLED	TRUCK NO.	MILEAGE WHEN INSTALLED	DATE REMOVED	MILEAGE WHEN INSTALLED	MILES ROLLED	COST	COST PER HUNDRED MILES	CAUSE OF REMOVAL
12575A	17DZ0893	6	Regular	Goodyear	600X16	6/28/55	8	156	5/14/56	47354	47198	25.42	.05	worn out
12574A	OVR515794	6	Mud Grip	Mansfield	650X16	1/23/56	8	38410	5/4/56	46868	8458	31.63	.37	worn out
12576A	DR517112	6	Mud Grip	Firestone	650X16	11/7/55	14	39354	5/12/56	53819	14465	36.86	.25	Broken

FIGURE 11 - Sheet 1 of 1

SOUTHWEST LOUISIANA ELECTRIC MEMBERSHIP CORPORATION

TRANSPORTATION EXPENSE FOR THE MONTH OF MAY 1956

TRUCK NO.	SPEEDOMETER MAY 1, 1956	SPEEDOMETER MAY 31, 1956	ESTIMATED MILEAGE	TOTAL MILEAGE	GALLONS OF GASOLINE CONSUMED	COST OF GASOLINE CONSUMED	MILES PER GALLON OF GASOLINE	QUARTS OF MOTOR OIL CONSUMED	COST OF MOTOR OIL CONSUMED	COST OF PARTS USED	LABOR	DEPRECIATION	INSURANCE	TIRES	TUBES	MISCELLANEOUS	TOTAL EXPENSE	COST PER HUNDRED MILES
1	93273	94405		1132	86.5	$22.77	13.1			$7.65	$6.28	$35.90	$8.08			$3.32	$84.00	$7.42
2	39939	42347		2408	222.8	59.84	10.8	7	$1.65	4.95	4.06	35.90	8.08	$26.81		3.32	144.61	6.01
3	3087	4653		1566	169.0	44.48	9.3	9	2.10	6.36	5.22	35.90	8.08			3.32	105.46	6.73
4	20794	21856		1062	143.8	37.85	7.4	9	1.65	59.48	48.82	35.90	8.08			3.32	195.10	18.37
5	30155	31567		1412	184.4	48.53	7.7	10	2.35	5.07	4.16	35.90	8.08			3.32	107.41	7.61
6	4522	5712		1190	148.8	46.76	8.0	4	1.60	3.27	2.68	35.89	8.08			7.00	105.28	8.85
7	90364	91367		1003	103.5	33.13	9.7	7	2.85	3.42	2.81	35.89	8.08			5.75	91.93	9.17
8	46350	49265		2915	224.9	72.99	13.0	30	13.07	3.27	2.68	35.89	8.08	63.74		9.62	209.34	7.18
9	38343	41177		2834	152.5	40.14	18.6	9	2.11	80.72	66.26	35.89	8.08			3.32	236.52	8.35
10	9679	11363		1684	110.3	29.03	15.3	7	1.65	5.06	4.15	35.89	8.08			3.32	87.18	5.18
11	26163	27395		1232	78.9	20.77	15.6	1	.24	3.27	2.68	35.89	8.08			3.31	74.24	6.03
12	19430	21725		2295	178.9	47.09	12.8	13	3.05	78.15	64.15	35.89	8.08			3.31	239.72	10.45
13	11234	12253		1019	90.0	23.69	11.3	8	1.88	12.06	9.90	35.89	8.08			3.31	94.81	9.30
14	52419	55862		3443	261.6	68.85	13.2	12	2.82	8.86	7.27	35.89	8.08	36.93	$3.42	3.31	175.43	5.10
15	12148	16110		3962	292.1	92.57	13.6	10	4.50	8.07	6.62	35.89	8.08			10.20	165.93	4.19
16	33218	35406		2188	137.0	36.05	16.0	6	1.41	7.95	6.53	35.89	8.09			3.31	99.23	4.54
17	968	2054		1086	147.9	49.65	7.3	6	3.60	138.94	114.05	35.89	8.09			10.05	360.27	33.17
18	5894	7582		1682	95.4	25.11	17.7	5	1.17	5.06	4.15	35.89	8.09			331	82.78	4.90
19	1829	2591		762	55.6	14.63	13.7	9	2.11	24.49	20.10	35.89	8.09			3.31	108.62	14.25
20	2133	3882		1749	120.9	31.82	14.5	6	1.41	22.81	18.72	35.89	8.09			3.31	122.05	6.98
21	81380	83464		2084	167.9	44.89	12.4	14	3.29	122.95	100.93	35.89	8.09			3.31	319.35	15.32
22	50191	51379		1188	168.8	56.16	7.0	14	6.09	3.27	2.68	35.89	8.09			11.55	123.73	10.84
23	43534	45100		1566	76.7	21.34	20.4	1	.24	3.27	2.68	35.89	8.09			3.31	74.82	4.78
24	50482	54200		3718	332.0	111.01	11.2	26	11.89	19.82	16.27	35.89	8.09			22.60	225.57	6.07
25	15418	16380		962	152.8	40.22	6.3	8	1.88	6.47	5.31	35.89	8.09			3.31	101.17	5.17
26	27932	30783		2851	175.9	46.30	16.2	8	1.88	689	5.66	35.89	8.09			3.31	108.02	3.79
				48999	4078.9	$1165.67	Avg. 12.0	237	$76.49	$651.58	$534.82	$933.19	$210.19	$127.48	$3.42	$139.73	$3842.57	$7.84 Average

FIGURE 12 - Sheet 1 of 1

ALUMINUM ALLOY CONDUCTOR IN DISTRIBUTION

By J. B. Roche
Kaiser Aluminum & Chemical Sales, Inc.
Chicago, Illinois

For Presentation at the 1957 Technical
Conference for REA Field Engineers,
New Orleans, Louisiana, January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

ALUMINUM ALLOY CONDUCTOR IN DISTRIBUTION

J. B. Roche

Aluminum conductor, either in the form of all-aluminum or as steel reinforced, has become the standard for transmission conductor. In distribution, however, its acceptance has been slow due to such problems as cost, which includes operating as well as initial and scrap costs, strength for sag purposes, lack of understanding of connections, and over emphasized corrosion problems in non-corrosive areas.

The acceptance of aluminum in distribution systems is indicated by the increasing spread between the costs of the two metals. Figure 1. shows the relative cost in cents per pound for both aluminum and copper. EC aluminum has only 61% of the electrical conductivity of copper, but due to its light weight, 1/2 lb. of EC aluminum has the same conductance as 1 lb. of copper. Hence, the reason for the bottom curve. Even though the price of aluminum is rising with copper, but not as sharply, the top and bottom curves depart more radically because conductor costs are based on 1/2 lb. of aluminum and 1 lb. of copper.

Aluminum's first inroads in distribution were for rural lines and triplex services. As the price of differential between copper and aluminum increased and more understanding developed towards the use of aluminum connectors, aluminum conductor moved into both primary and secondary distribution applications.

For many of these applications, all-aluminum, as will be shown, does not have the strength to meet sag requirements, particularly in the smaller sizes. ACSR, on the other hand, has been satisfactorily used and will undoubtedly meet the requirements set up by most engineering organizations. It has been used; is relatively inexpensive; accessories are available; and crews have become familiar with handling it. Complaints from serviceability are limited.

Utilities, however, that have been using copper conductor in distribution in many cases want a conductor that can be handled simply, repaired quickly, has the necessary strength, and operates inexpensively. Composite conductors cannot meet all these requirements. The only way that an all-aluminum conductor can fit is to use a high strength

aluminum alloy.

ALUMINUM ALLOYS

There are two main types of aluminum alloys, heat treatable and non-heat treatable.

Heat-treatable alloys contain alloying elements which tend to participate out of the solution. To prevent this, it is necessary to employ a combination of cold working and heat treating to develop the physical properties.

Non-heat treatable alloys require only cold working to develop the mechanical properties of the alloy.

Standard EC aluminum is a non-heat treatable, whereas AAAC (triple AC) is a heat treatable alloy.

PROPERTIES OF EC AND ALLOY ALUMINUM

Table I tabulates comparitive physical properties of both metals. ASTM specification B-230 defines the requirements for hard drawn EC aluminum wire. AAAC, an aluminum-magnesium-silicon alloy, is not covered by such an industry standard and is supplied to Kaiser's own manufacturing specifications. EC has an aluminum content of approximately 99.45, which, incidentally, is no longer required by specification. The remainder is impurities. AAAC has an aluminum content of approximately 98.5%. The balance is made up of magnesium, silicon and a very small percentage of impurities.

In alloying aluminum even though there is only slight reduction in the primary metal content, there is, as with other metals such as copper, an appreciable decrease in electrical conductivity. In the case of aluminum it drops from a minimum of 61 to 52% IACS.

The resultant resistivities in ohms (mil ft.) units changes from 17.002 for EC to 19.945 for AAAC.

The density and, therefore, the unit weight of the metal remains the same. For any given conductor resistance a greater metal weight or cross sectional area is necessary. In this case 17.3% greater weight of alloy is necessary for a conductor having the same d-c resistance as EC aluminum.

The only other factor which changes with the alloy is the temperature coefficient of

resistance which changes from .00403 for EC to .00340 for AAAC. Both the modulus of elasticity and coefficient of expansion remain the same for both EC and AAAC.

COST CONSIDERATION

Of prime interest, is the cost of the conductor. It is mentioned here only since in describing the alloy, fabrication methods are discussed to show how the properties of the metal are obtained.

EC aluminum is pure aluminum, can be directly cast, rolled, drawn and stranded into conductor. Its physical properties are developed by cold working during the rolling and drawing operation.

AAAC, on the other hand, has a critical alloying and casting operation, requires special rolling procedures, solution heat treatment to maintain alloying elements in solution, drawing procedures and heat stabilization to develop its physical properties.

For any particular application, EC aluminum, if it can meet sag requirements, is and will remain the most economical conductor on a footage basis. ACSR will be next in line, since it has the same amount of aluminum as EC and, in addition, a steel core. The alloy conductor will be more expensive on a footage basis than ACSR due to the fabricating operations outlined about as well as the 17% additional aluminum content due to its lower conductivity[1].

REASONS FOR USING ALLOY CONDUCTOR

The idea of using high-strength aluminum for electrical applications is not new. Modified alloys have been used in various European countries since 1927 under such names as Almelac, Silmalec, Aldrey and others. Experimental installations have been made in the United States for such applications as signal wire and transmission conductor, but there have been no recorded installation in distribution systems.

CORROSION

To consider using alloy conductor there must be problems that the alloy can solve. If corrosion is one, the use of alloy conductor is fully justified. Aluminum, as you know, forms an oxide on its outer surface. Any chemical corrosion must first dissolve

this oxide, which is unaffected by most common atmospheres.

Purity of aluminum is a factor in considering chemical corrosion. Of prime importance also, however, are the elements which make up either the alloy or constitute the impurities. The resistance of the alloys containing silicon, such as the alloy considered here, is only slightly reduced from that of pure aluminum. On the other hand, alloys containing copper are known to be highly susceptable to corrosion.

Besides chemical corrosion there is the problem of galvanic corrosion. This has been significant in many locations and some utilities do not use ACSR in knownhigh corrosion areas. Where ACSR cannot be used, either all-aluminum, or alloy conductor should be used. It is also possible to use ACSR with either a "B" or "C" coated core wire. However, as long as two metals are present (zinc and aluminum, or steel and aluminum), there is a continuing galvanic action in corrosive atmosphere and coatings only postpone failure.

STRENGTH AND SAG REQUIREMENTS

It has been pointed out previously that the smaller sizes of aluminum conductor do not have the strength to meet sag requirements often established in urban distribution systems. It is common practice for many people to use ACSR in sizes up to and including 1/0, and above 1/0 to use EC aluminum. Othere use ACSR in all the AWG sizes.

Table II is prepared for a 150 ft. span and is based on all sizes of conductor being installed with 23" of initial sag at 60° F. From the number of requests for sag information received, it is felt that these are representative governing conditions. You will note that for bare conductor requirements it is recommended that ACSR rather than all-aluminum be used in sizes up to 1/0 if these sag requirements must be met.

If No. 4 AWG EC conductor is installed with 23" of initial sag at 60° F. in a 150 ft. span, and at a later date is subjected to the heavy loading district conditions of 1/2" ice and 4 lbs. wind, the tension will exceed the rated 826 lb. conductor strength. If ACSR is used, it is loaded to 41% of its strength. If No. 4 AWG equivalent alloy conductor is used, it is loaded to only 40.3% of its strength. The clearance or 60° F. final sag difference is only 2" for aluminum alloy and ACSR conductors. At higher

temperatures, such as 120° F, the alloy conductor has 6 to 8" more sag than the ACSR conductor.

If neoprene weatherproof is considered and the same sag requirements are imposed, then it is recommended that ACSR be used up to 4/0 AWG. If polyethylene is used, then ACSR should be used through 2/0 AWG. This restriction is based on the fact that under the NESC, 5th Edition, heavy loading conditions, the conductor tension would exceed the maximum recommended tension of 50% for EC aluminum. The alloy conductor, on the other hand, can be used satisfactorily in equivalent sizes from No. 4 AWG through 4/0 and will have approximately the same 60° F. final sags as ACSR.

While on the subject of tension in the conductor, it might be well to mention the vibration fatigue or endurance limit of the alloy. Vibration is dependent upon a constant cross wind blowing on conductor which builds up eddys on the lee side and causes conductor motion. In urban areas there are obstacles which ordinarily break up this constant wind pattern and vibration is not a critical problem. Tensioned conductors in exposed rural areas are armored to lessen the problem of fatigue. In fact, some form of dampening may be necessary. The fatigue endurance limit of a conductor is the stress it can stand for 500,000,000 cycles without strand breakage. The maximum stress value for hard drawn ED aluminum is accepted as 7,000 PSI; medium hard drawn copper is 8,000 PSI. For what is called AAAC, present information indicates that this value will fall between 12,000 and 13,000 PSI.

Is distribution, as has been shown, ordinarily the tensions imposed on conductors will result in stresses which are below the alloy endurance limits.

BEND CHARACTERISTICS

Two properties have been selected which can be considered indicative of the ease in handling wire. Table III shows the torque necessary to wrap the conductor about its own diameter. The sizes shown are electrically equivalent. Hard drawn aluminum is the easiest to handle. No. 4 AWG solid requires a torque of only 45 in. lbs. while No. 6 hard drawn copper requires slightly more than this -- 50 in. lbs. No. 4 equivalent

aluminum alloy requires 65 in. lbs. This is due partially to being a harder metal, as well as the wire being 30% larger in diameter. For such applications as solid neutrals for service drop conductor, the temper of the wire would be reduced and the required torque lessened. In conductor, strands would not be this large and the torque required to bend the conductor would be much less than this figure indicates.

As an indication of the conductor stiffness, 1/0 ACSR and its equivalent AAAC were wrapped about a 2-1/4" mandrel. The ACSR required 12 ft. lbs. whereas the AAAC required 13. About a 4-1/4" mandrel the ACSR required 10 ft. lbs. and the AAAC required 11.

The 90° bend-to-failure information is based again on bending the conductor about its own diameter, but only to 90° and each bend followed by a 90° reverse bend. No. 4 AWG EC can withstand 16.25 reverse bends, while electrically equivalent No. 6 hard drawn copper and No. 4 AWG equivalent AAAC can withstand 6 and 6.6 bends respectively. Medium hard drawn copper is only slightly better and can withstand 8 reverse bends.

CONDUCTOR DESIGN

Table IV shows that the conductors ACSR and AAAC are designed to have approximately the same d-c resistance at 20° C.

Since the conductivity of EC aluminum is 61% and that of the alloy is 52% in the 4/0 equivalent size, for the same d-c resistance the cross sectional area of the alloy conductor will be greater by the ratio 61/52=1.173. It will also be greater than the aluminum area of ACSR conductor by the same factor, since the conductance of the steel core is neglected.

This increased area, necessary when AAAC is used, results in a conductor diameter larger than EC aluminum, but for all practical purposes, the same as ACSR in the AWG sizes. The diameter of the conductor is listed here to show that both conductors have the same diameter and hence the same radiating surface.

Figure 2 compares the resistance of No. 4/0 - 6/1 ACSR and No. 4/0 equivalent AAAC. Note that for a current of 300 amps and a cross wind velocity of 2 ft/sec the 60 cycle a-c resistance of No. 4/0 ACSR is .105Ω/1000 ft, while that of No. 4/0 equivalent aluminum alloy is only .086Ω/1000 ft, or the alloy has 18.1% less resistance than ACSR at

this value of 60 c.p.s. current.

This reduction in operating resistance is important, but in addition, there is also lower reactance if AAAC is used. Table V is prepared for No. 4 AWG EC aluminum and its equivalents, and No. 3/0 AWG EC and its equivalent in AAAC and ACSR.

While No. 4 AWG EC aluminum may not have the strength to meet sag requirements, it does have a lower resistance and reactance than does ACSR. This difference is slightly greater if alloy conductor is used. The reason, of course, is that for a given current, the current density in alloy conductor is less than in EC aluminum. Another factor is that the temperature coefficient of resistance is less for alloy than for EC.

This reduction in operating resistance and inductive reactance is magnified in the 3/0 equivalent size.

The current carrying capacity for ACSR and alloy conductor is dependent upon the resistance which determines the temperature rise. Figure 3 shows the conductor temperature rise, for 4/0 equivalent conductors, about a 25° C. ambient, test condition includes the factor of 2 ft/sec cross wind. If the allowable temperature rise is 50° C., the current carrying capacities of AAAC and ACSR are respectively 425 amps and 382 amps.

The factors of current carrying capacity, operating resistance and inductive reactance are important when considering the economic conductor size. Due to the variations in accounting procedures and power loss charges, their relative importance in this selection is outside the scope of this paper. The 10% increase in current carrying capacity and the 20% lower power loss for equal current due to the lower resistance, together with the reduction in total impedance, which would influence voltage correction methods, must definitely be taken into consideration in economic conductor selection.

CONDUCTOR ACCESSORIES

In a companion paper, "Inherent Design Factors in Connecting Aluminum Conductors", by Mr. C. G. Sorflaten, the basic factors involved when connecting aluminum conductors are discussed. There are a few general remarks required here which deal particularly with accessories for alloy conductor.

ACSR ACCESSORIES USED ON ALLOY CONDUCTOR

Since conductors of equivalent resistance in alloy are the same physical size or diameter as the ACSR that they can replace in a distribution system, common bolted type dead ends or taps for use on ACSR have been tested satisfactorily on AAAC (triple AC).

Aluminum compression splices for ACSR for full tension splice have not proven satisfactory as a general class for AAAC. The main reason for this is that from a tension standpoint, the aluminum body of an ACSR splice is designed by many manufacturers to hold only the strength of the aluminum strands which is approximately 1/2 the conductor strength. The steel splice of the core develops the other half. For AAAC, the aluminum sleeve must be so designed to hold the full conductor strength without any core splice.

Such manufacturers as Burndy, Preformed Line Products and Kearny have accessories which can develope the full conductor strength without special installation procedures.

The single splice unit of AAAC offers a great advantage to users especially for hot line applications, as compared to ACSR. Both Fargo and Reliable have become interested in alloy conductor and have automatic splices which do not require the outer layer of strands be cut back to separately grip the core wire. If this type accessory is accepted as standard on copper wire, there is every indication that its use on alloy will be in every way as acceptable.

SUMMARY

In summary, I believe it should be noted that:

1. If EC aluminum can supply the strength necessary, this conductor will be the advisable choice for use in distribution.
2. If strength greater than EC is necessary, use either ACSR or AAAC. When first cost only is considered, ACSR will be less costly. If operating cost is included the balance can swing in favor of AAAC.
3. In corrosive areas it is advisable to use AAAC rather than ACSR.
4. In normal distribution, the operating advantages such as lower voltage drop, lower power loss, and higher current carrying capacity, plus the reduced maintenance charges offered by high strength, single splice conductor may swing the

economic conductor selection to the use of alloy rather than in favor of the lower initial cost of ACSR.

TABLE I

BASIC PROPERTIES OF ALUMINUM

	STANDARD HARD-DRAWN E. C. ALUMINUM	AAAC
ALUMINUM CONTENT (PER CENT	99.45	98.5
VOLUME CONDUCTIVITY - 20° C. PER CENT IACS	61.0	52.0
RESISTIVITY @ 20° C. OHMS - CM - FT.	17.002	19.945
DENSITY @ 20° C. GRAMS PER CUBIC CM	2.703	2.703
WEIGHT - LBS. PER CUBIC IN.	.09765	.09765
RATIO OF WEIGHT FOR EQUAL RESISTANCE AND LENGTH	1.000	1.173
TEMPERATURE COEFFICIENT OF RESISTANCE, PER °C. @ 20° C.	0.00403	0.00340
COEFFICIENT OF LINEAR EXPANSION INCH/INCH °F.	0.0000128	0.0000128
MODULUS OF ELASTICITY	10,000,000	10,000,000

J. B. Roche

TABLE II

BARE CONDUCTOR - SAG DATA

	No. 4 AWG			No. 1/0 AWG			No. 4/0 AWG		
HEAVY LOADING	E.C. 7 Strand	ACSR 6/1	AAAC 7 Strand	E.C. 7 Strand	ACSR 6/1	AAAC 7 Strand	E.C. 7 Strand	ACSR 6/1	AAAC 7 Strand
(0° F, 1/2" ICE, 4# WIND + K)									
SAG (IN.)	LOADED	44	48	40	33	35	38	26	26
TENSION (LBS.)	CONDITION	750	685	920	1200	1095	1420	1840	1725
% OF ULTIMATE STRENGTH	EXCEEDS	41.0	40.3	49.4	28	25.5	25	21.9	20.5
FINAL - 60° F.	BREAKING								
SAG (IN.)		29	31	35	27	28	29	25	25
TENSION (LBS.)	STRENGTH	67	52	103	184	137	244	384	310
FINAL - 120° F.									
SAG (IN.)		35	43	45	33	40	42	33	39
TENSION (LBS.)		55	35	74	145	95	168	301	202

ALL CONDUCTORS INSTALLED AT 23" INITIAL SAG AT 60° F.

J. B. Roche

TABLE III

BEND CHARACTERISTICS

OF CONDUCTOR

	90° BENDS TO FAILURE	WRAPPING TORQUE INCH-POUNDS
#4 AWG (0.204") H. D. ALUMINUM	16.25	45
#6 AWG (0.1620") H. D. COPPER	6.0	50
#6 AWG (0.1620") M. H. D. COPPER	8.0	50
#4 AWG EQUIV. (0.210") AAAC*	6.6	65

* EQUIVALENCY IS TO E. C. ALUMINUM RATHER THAN COPPER.

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TABLE IV

CONDUCTOR PHYSICAL DATA

	NO. 2 AWG			NO. 3/0 AWG		
	EC 7 Strand	ACSR 6/1	AAAC 7 Strand	EC 7 Strand	ACSR 6/1	AAAC 7 Strand
AREA (IN.^{2})						
ALUMINUM	0.0521	0.0521	0.0600	0.1318	0.1318	0.1548
STEEL	-	.0087	-	-	0.0220	-
TOTAL	0.0521	0.0608	0.0600	0.1318	0.1538	0.1548
CONDUCTOR						
DIAM. (IN.)	0.292	0.316	0.314	0.464	0.502	0.503
STRENGTH (LBS.)	1267	2790	2700	2847	6675	6687
WEIGHT (LBS/MFT)	62.3	91.3	71.4	157.5	230.8	184.1
D-C RESISTANCE AT 20° C. (OHMS/MFT)	0.261	0.261	0.260	0.1034	0.1029	0.1029

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TABLE V

ELECTRICAL CHARACTERISTICS

OHMS AT 60 CPS PER 1000 FT (50° C.)

NO. 4 AWG	A-C RESISTANCE	REACTANCE TO NEUTRAL (18" EQUIV. SPACING)	IMPEDANCE PER CONDUCTOR
EC - 7 STRAND	0.4660	0.1233	0.483
ACSR - 6/1	0.487	0.1343	0.503
AAAC - 7 STRAND	0.460	0.1217	0.476
% BELOW ACSR:			
EC	4.3	8.2	4.0
AAAC	5.5	9.4	5.4

NO. 3/0 AWG			
EC - 7 STRAND	0.1160	0.1073	0.158
ACSR - 6/1	0.1370	0.1273	0.187
AAAC - 7 STRAND	0.1144	0.1055	0.156
% BELOW ACSR:			
EC	15.3	15.7	15.5
AAAC	16.5	17.1	16.6

J. B. Roche

FIG. 1

AVERAGE BASE METAL PRICE

CENTS / LB.

(SOURCE– AMERICAN METAL MARKET)

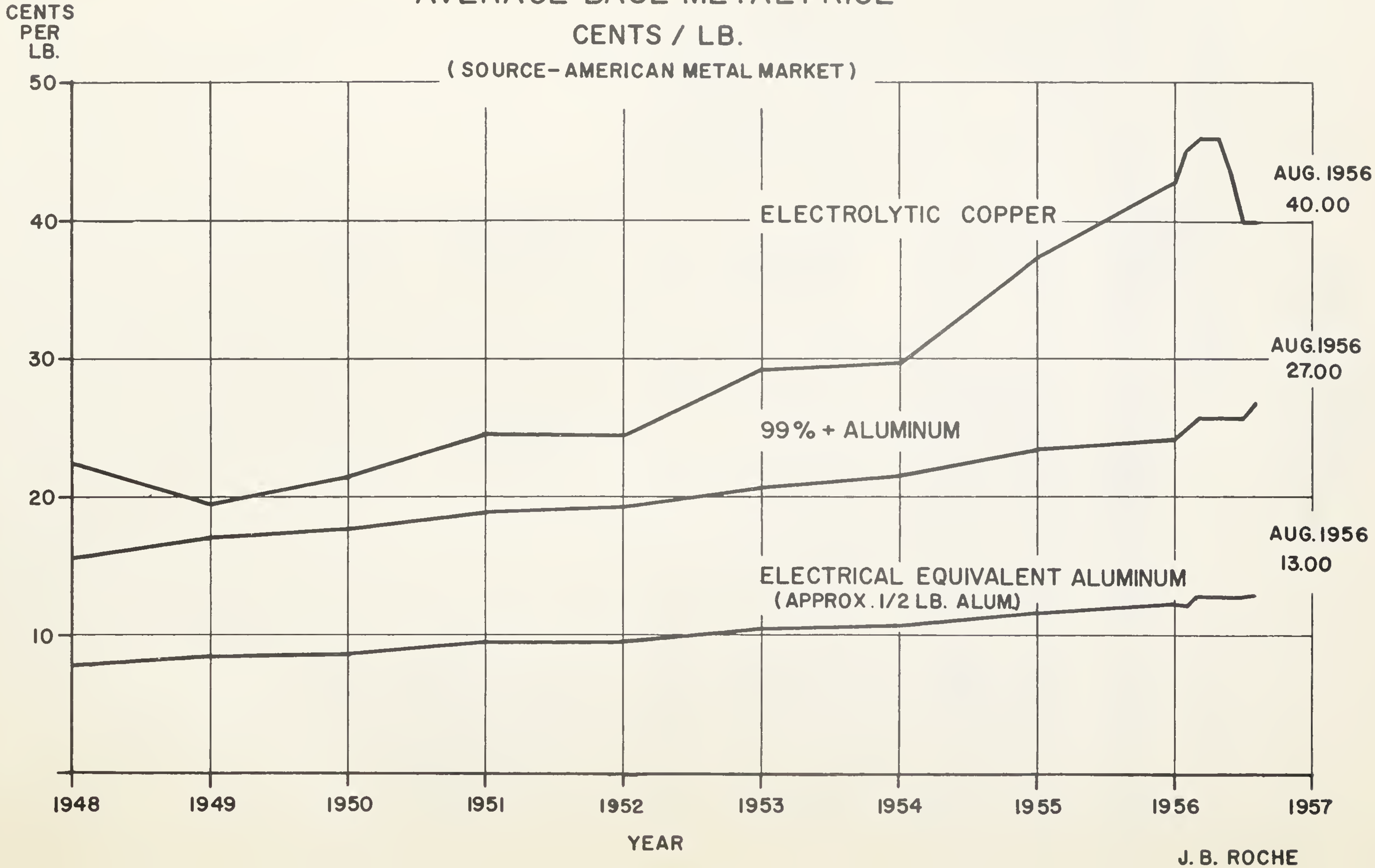
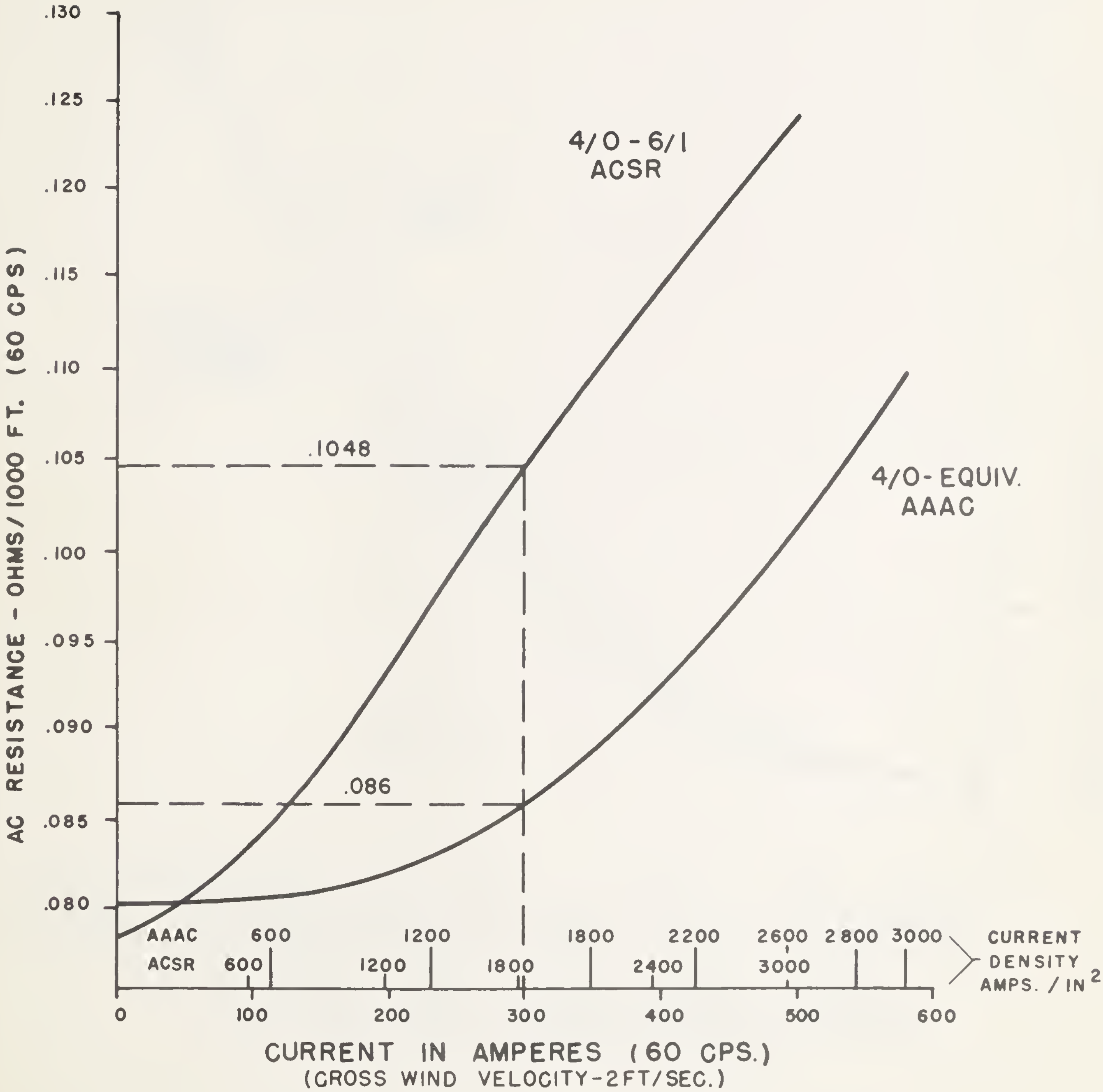


FIG. 2

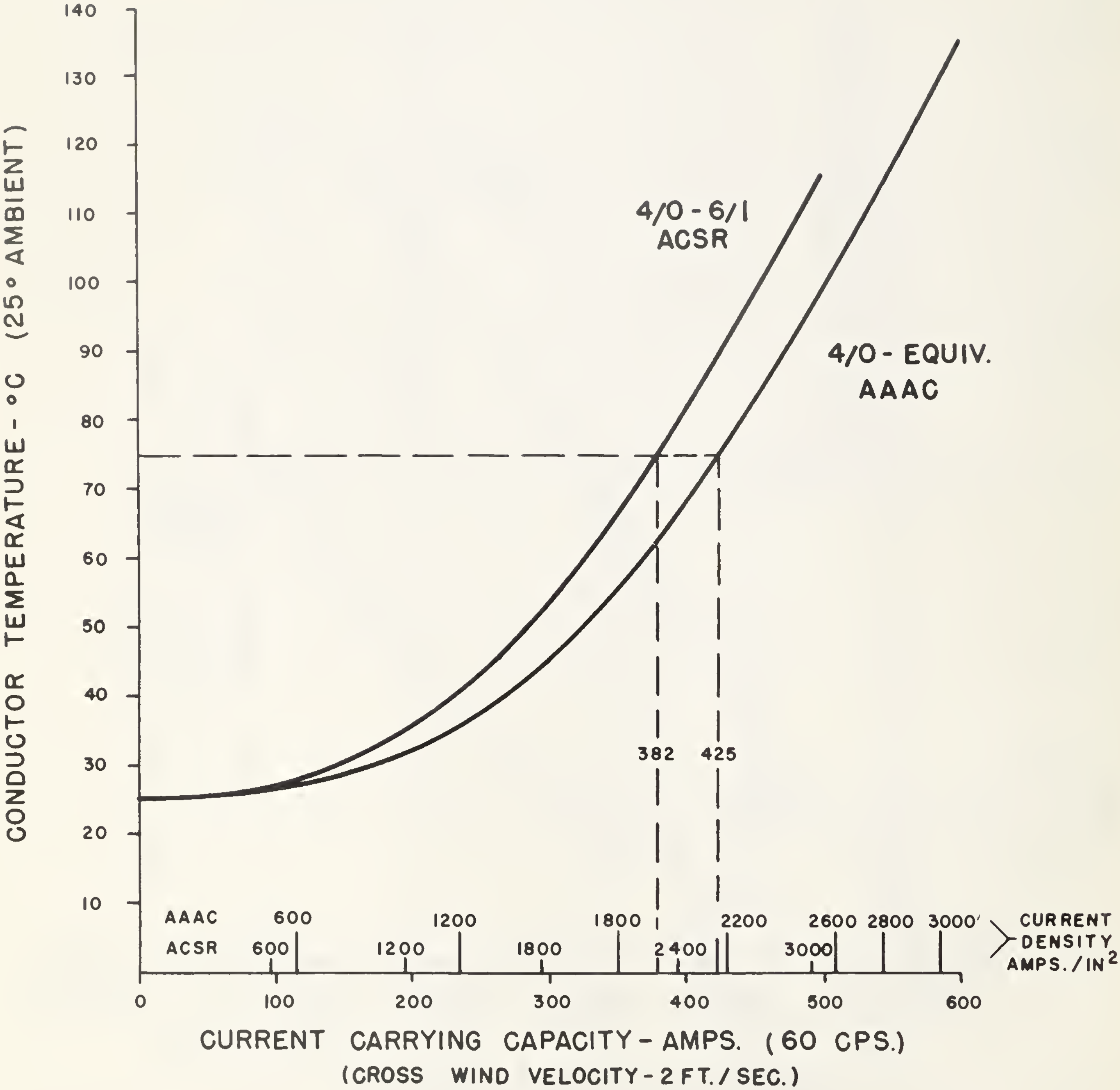
EFFECT OF 60 CPS CURRENT ON A-C RESISTANCE OF 4/0-6/1 ACSR & 4/0 EQUIV. AAAC



J.B. ROCHE

FIG. 3

CONDUCTOR TEMPERATURE VS. 60 CPS. CURRENT



J.B. ROCHE

INHERENT DESIGN FACTORS IN CONNECTING ALUMINUM CONDUCTORS

By C. G. Sorflaten
Kaiser Aluminum & Chemical Sales, Inc.
Chicago, Illinois

For Presentation at the 1957 Technical
Conference for REA Field Engineers
New Orleans, Louisiana, January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

INHERENT DESIGN FACTORS IN CONNECTING ALUMINUM CONDUCTORS

C. G. Sorflaten

The use of aluminum conductor on overhead distribution systems has been accelerated by copper shortages and economic considerations. The reluctance of some to adopt aluminum has been and still remains, the great concern over the proper types of connectors to use. The fact that a majority of the utilities are using aluminum in increasing amounts despite this concern over proper connectors argues well for the future of aluminum conductor. This growth also means an expanding use of connectors for aluminum and hence it produces an incentive to develop new improved types and to limit the substitution of connectors that were designed primarily for copper conductors. This trend is well under way, as evidenced by new connector catalogs issued by connector manufacturers listing only connectors for aluminum conductors or for making aluminum to copper connections.

The differences between copper and aluminum are not great and require only slight modifications in our basic concepts to evaluate and select reliable connectors for aluminum conductor. These differences can be visualized more easily by reviewing the fundamental principles involved in making an electrical connection. Fig. 1 shows the physical relationship between stranded conductor and the contact surfaces of a connector. The initial contacts between the connector and either stranded aluminum or copper conductor, are line contacts where the crests of the outer strands contact the connector surfaces. These line contacts broaden when the connector is tightened because they do not have sufficient area to support an applied load. To thus deform the conductor, the elastic limit of the conductor material is exceeded at these lines of contact and deformation continues as long as the unit pressure remains above the elastic unit. The amount of contact area generated will increase with each successive increase in load until the sum total of the contact areas is sufficient to support the total applied load. The unit pressure on these contact areas not only exceeds the elastic limit during the tightening process but after tightening has been accomplished, the conductor still remains stressed above the elastic limit and slowly continues to deform. This is the normal relaxation to be expected after tightening a bolted fitting on any stranded conductor.

This can be shown graphically by referring to the conductor stress-strain curves in

Fig. 2. The upper curve shows the stress vs. deformation relationship for hard drawn copper conductor and the lower for hard drawn E. C. aluminum conductor.

The points A and A' represent the elastic limits of hard-drawn E. C. grade aluminum and hard-drawn copper, respectively. The points B and B' represent the maximum momentary stress and is reached during the tightening process, and the distances from B to A_1 and from B' to A_1' represent the normal relaxation of the conductor after the initial tightening.

It is the continued deformation of both the conductor and fitting after tightening that relieves the initial applied pressure in a bolted connection. The conductor in the precess of deforming develops more contact area while slightly changing its contour. This deformation is rapid immediately after tightening and slows up as the elastic limit of the conductor material is approached. Knutz & Shahfer[3] have reported that of the total amount of this change in pressure, a major part was lost in the first 5 minutes. This value was reported in tests made on stranded copper conductor. The final stabilized unit pressure that a connection ultimately reaches is in the vicinity of the elastic limit of the conductor material as represented by points A_1 and A_1' on the stress-strain curves. This unit pressure will be approximately the same regardless of the magnitude of the tightening torque, because the elastic limit is exceeded almost from the first application of torque. Definite values for the elastic limit of aluminum and copper conductors are difficult to assess since the gradual creep toward this point may take place over a period of years, with an accompanying slight reduction in total pressure.

Results of tests made on aluminum conductor show that after a short relaxation period the unit pressure is close to 10,000 psi and that this value is representative for bolted connectors that apply either a high total pressure or a low total pressure. For comparative purposes and to establish the above 10,000 psi unit pressure comparative data were taken

REFERENCES

1. Connector Limitations, R. M. Shahfer, W. H. Knuts. Electrical World, New York, N. Y., January 31, 1948

for a single bolt parallel groove clamp and a loop dead-end clamp of the U-bolt type. Both of these clamps have the same diameter bolts, the same number of threads per inch and both are galvanized so that with equal tightening torques each bolt will develop approximately the same total clamping pressure. The total pressure that is applied to the conductor in these clamps, however, will depend upon the mechanical advantage developed by the clamp. These clamps were selected for testing because of the great difference in total conductor pressures for equal tightening torques. Actual pressures exerted on the conductors in these clamps will be approximately in the ratio of 1 to 4. This is represented in Fig. 3.

In the parallel groove clamp 1/2 of the total pressure, P, is applied to each conductor while in the loop dead-end clamp the pressure on both conductors is the sum of the pressures developed in each leg of the U-bolt. The ratio of the final stabilized total conductor pressures in the two fittings, then, should be in the ratio of 1 to 4 if equal tightening torques remain in each of the bolts when the clamping pressures have become stabilized.

The projected contact areas that were developed in these two clamps were measured after a short relaxation period and they were found to be approximately in the ratio of 1 to 4, i.e., the loop dead-end clamp developed approximately 4 times as much total contact area as the parallel groove clamp. Translating the final torque into terms of approximate bolt pressure, the unit pressure in each connector was calculated by the fundamental relation:

Total load = psi x contact area (square inches)

The unit pressures in both of these connectors was found to be approximately the same, and the amount of contact area developed to vary directly with the applied total stabilized pressure. It is to be appreciated that this relationship is only true where the amount of deformation on each strand is small in proportion to strand diameter and this relationship cannot be applied to compression fittings or to cases of excessive strand deformation.

Having determined the stable unit pressure in a bolted connection on stranded conductor as a value near the elastic limit of the conductor material, it then becomes important to maintain this high unit pressure for the life of the connection. This is an important consideration in maintaining a long life connection with any conductor, and fittings should

first provide for this feature. Causes of relaxed pressure in connectors after they have become stabilized can be attributed to many variables, the important ones of which may be listed as follows:

1. Creep of the conductor which is accelerated at high temperature.
2. Creep of the fittings due to high stresses. This also is accelerated by high temperatures.
3. Effect of dissimilar metals with different coefficients of thermal expansion.

As mentioned previously stabilized conductor unit pressures are attained near the elastic limit of the conductor material, however, this indefinite point is approached at a continually decreasing rate of deformation or creep only if constant temperature is maintained. If temperatures are raised, a higher rate of creep is automatically attained and the rate of deformation of the conductor becomes more rapid, which in turn is accompanied by a loss of applied pressure. The higher the temperature and the longer the duration, the greater will be this loss in pressure.

Likewise, the connector itself if highly stressed will also be subjected to a higher rate of deformation or creep at high temperatures. The magnitude of the relaxation of the fitting is also dependent upon the degree of heating and the length of time at the elevated temperature.

The effect of dissimilar metallic materials in an electrical connection may also cause ultimate loss of pressure in a connection. The usual applications find an aluminum conductor with its high coefficient of expansion connected within the confines of a copper bodied connector with its lower coefficient of expansion, or an aluminum conductor and aluminum alloy fitting retained by steel bolts with a still lower coefficient of expansion. High temperatures will cause an increase of pressure on the conductor in such fittings and an increased stress in the body of the fitting. This increased pressure initiates the same relaxation period that followed the initial tightening of the fitting. This effect on the ultimate loosening of the connection, however, is not considered to be as serious as the relaxation of conductor and fitting. In each case, however, the loss of pressure can be attributed to an increase in temperature and attests to the value of heat cycling tests to determine the action of a connection. It's difficult to remedy effects of heat cycling

since seasonal temperature changes, overload currents, and short circuit conditions are inherent in a distribution system. However, design provisions can limit the effects of heat cycling to a minimum. The creep rate of the conductor must be accepted as inevitable and rises in temperature will be accompanied by a slight increase in the rate of creep where the conductor is stressed to a value that gives a significant creep rate. The connector parts, however, can be designed of such proportions that the application of pressure will not stress the parts to values near the elastic limit where high temperatures will induce significant rates of creep. And finally to eliminate relaxation induced by connecting aluminum conductors in fittings of dissimilar materials the remedy is quite apparent - use as nearly as possible fittings of the same material as the conductor or provide some additional means of an elastic nature to compensate for the different rates of thermal expansion in the connection.

The exact pattern or formula to use in the selection of a connector should probably be based on the features of the most successful types of fittings being used today. If we were to select one type of fitting that we would all recognize as being the closest to the ideal connector, it would be a compression fitting, either a compression splice or a compression dead-end. It would be wise, then, to incorporate the features of a compression fitting in bolted fittings that are selected for distribution use. These features can be enumerated as follows:

1. Extremely high applied total pressures by compression tools.
2. Curvature of wire bearing groove conforms to the shape of the conductor.
3. Proper length is provided to the conductor groove.
4. Materials are usually the same as the conductor.

High pressure has always been a criterion for a good electrical connection. It is just as true with aluminum conductor. The oxide film on the strands can be wire brushed from the outer surface, but the interstrand contacts cannot be effectively cleaned. To obtain good interstrand contacts, compounds containing abrasive particles are an aid to penetrating the film, but high pressure can be extremely effective in dissociating the oxide from these areas. The desirable effects of high pressure are many and may be listed as follows:

a. More contact area is developed

b. Interstrand contacts are improved

c. Substantially higher total pressures will remain after relaxation

d. Heat cycling is minimized by more contact areas and lower interstrand resistance. The connection will thereby operate at a lower temperature.

In order to apply high pressures, the fitting must also incorporate the two dimensional quantities listed for compression fittings, i.e., (1) curvature of the conductor groove should fit the conductor as closely as possible, and (2) the connector groove should be of sufficient length to distribute the applied pressure uniformly amoung all the outer strands of the conductor.

When the curvature of the connector groove fits the curvature of the conductor, equal contact is made as nearly as possible with all outer strands, and equally important on ACSR, the strands are compressed tightly around the steel core wire which aids in protecting the core from exposure and possible galvanic corrosion. This will, of course, discourage the use of fittings with universal wire ranges because it is difficult to properly fit the curvature of a connector groove with more than a range of 2 AWG sizes. This also means that separators between conductors are recommended practice, and where used, they should also conform to the curvature of both conductors.

The length of the connector groove should also be such that the applied load can be distributed more equally among the strands and thus assure an equal distribution of current carrying areas among all the outer strands, or where the fitting is used for a dead-end it assures the equal distribution of tension among the outer strands. The spiral lay of the strands tends to rotate the strands within the connector and thereby aid in this equal distribution of contact area. On tensioned lines, a properly proportioned length of groove aids in preventing a longitudinal migration of metal towards the ends of the connector which might reduce the cross-sectional area and thereby reduce the breaking strength of conductor.

With a properly proportioned connector as described above, a high pressure may be applied just as in a compression fitting, and after the connector has been installed and

the normal relaxation period has left the connection with a high stabilized pressure, this high pressure can be further assured if the connector materials have the same coefficient of thermal expansion as the conductor. If it is desirable to use dissimilar materials, a high uniform pressure can be maintained by incorporating a spring device to compensate for the differences in rates of thermal expansion.

An additional requirement of a connector is a provision for corrosion resistance, since many connections will be made between copper and aluminum conductors. Several schools of thought prevail on this subject and they may be listed as follows:

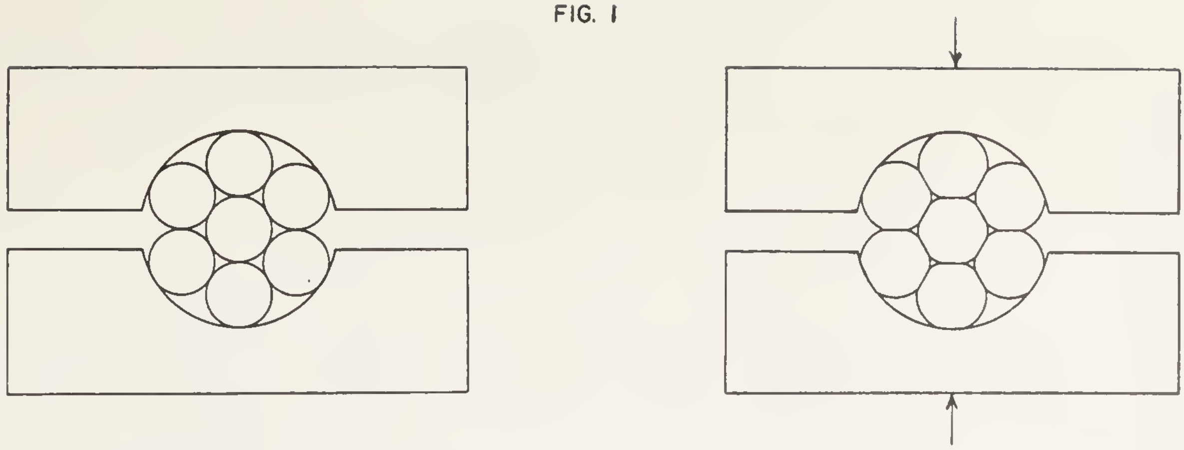
a. Provide heavy section, closely fitting, aluminum connector parts to enclose the copper conductor and thereby distribute galvanic currents over a large section of the aluminum fitting. A closely fitting connector body limits the amount of exposed copper conductor and the heavy section of the aluminum connector body reduces the density of the galvanic currents. The resulting corrosion is thereby well distributed and its effect is negligible.

b. Provide hot-flowed tin plating to connectors to act as a buffer between the dissimilar conductor materials.

c. Provide heavy deposits of cadmium plating to connectors as a buffer between the dissimilar metals.

The best method to use in providing corrosion resistance will depend to a large extent on the severity of corrosion in the area in which the fitting is to be used. It may be entirely satisfactory in most localities to rely on the provisions outlined in (a), but in areas where corrosion is a serious problem, it may be advisable to specify heavy deposits of tin or cadmium as outlined in (b) and (c) to achieve the desired protection. The use of a good inhibiting grease or compound at the time of installation is a recommended practice regardless of the method used to combat corrosion.

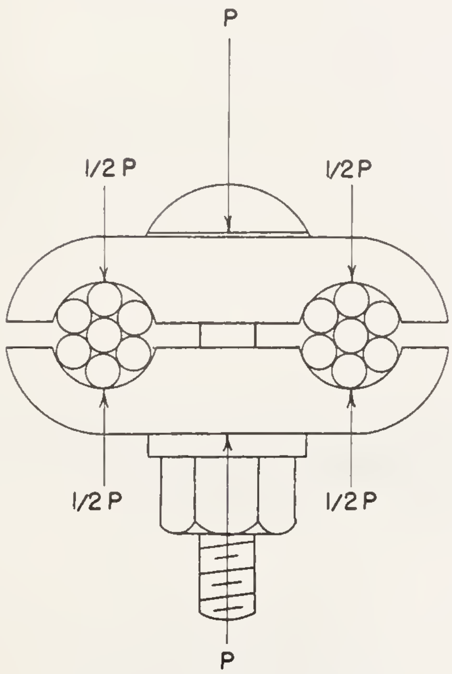
FIG. 1



INITIAL CONTACTS - ARE LINE CONTACTS BETWEEN THE CRESTS OF THE CONDUCTOR STRANDS AND THE CONNECTOR SURFACES.

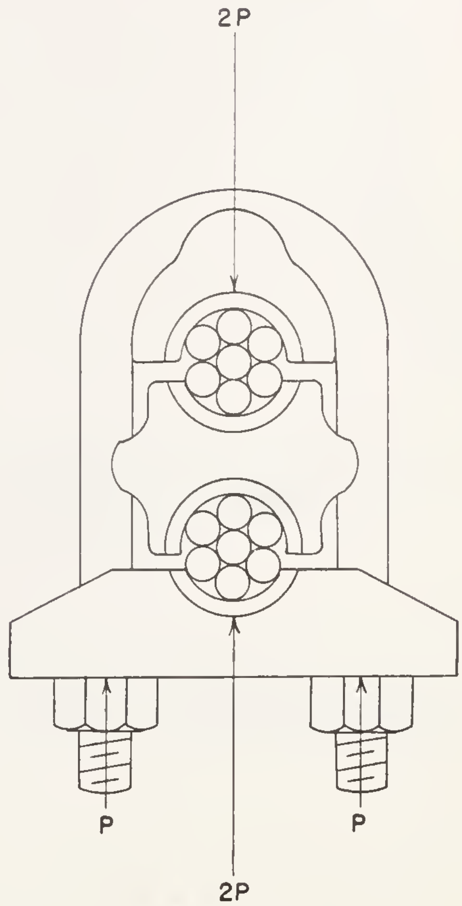
DEVELOPED CONTACT AREAS - ARE THE RESULT OF THE BROADENING OF THE INITIAL LINE CONTACTS.

FIG. 3



PARALLEL GROOVE CLAMP

APPLIED PRESSURE = P
CONDUCTOR PRESSURE = 1/2 P



LOOP DEAD-END CLAMP

APPLIED PRESSURE = P (EACH LEG)
CONDUCTOR PRESSURE = 2 P

C.G. SORFLATEN

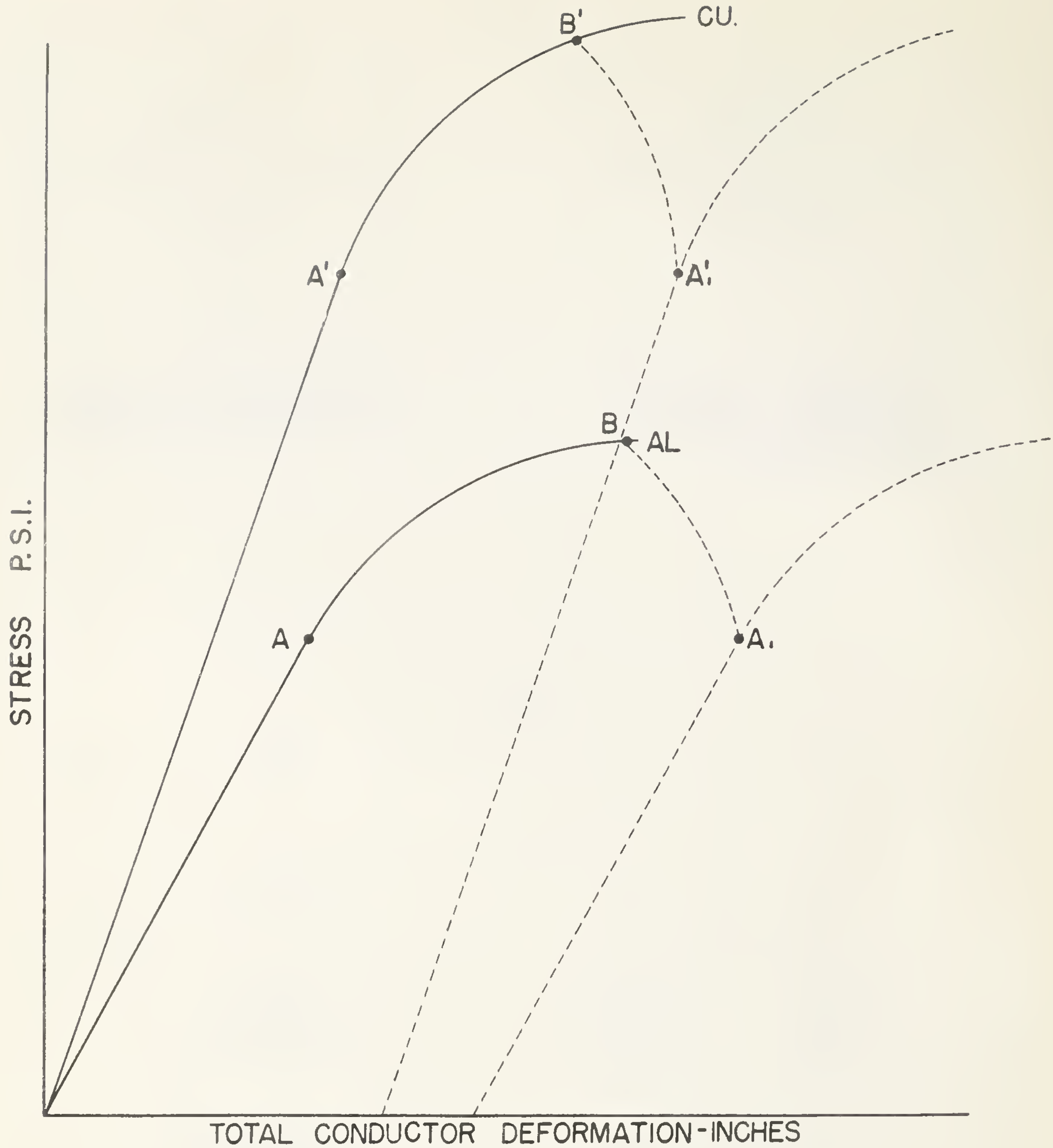


FIG. 2
CONDUCTOR STRESS - VS - DEFORMATION

C.G. SORFLATEN

TRAINING COURSES FOR METERMEN

By Harold W. Kelley
Meter and Service Engineer
Electric Engineering Division

For Presentation at the 1957 Technical Conference for REA Field Engineers
New Orleans, Louisiana, January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural Electrification Administration

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R. G. Zook
Assistant Administrator

TRAINING COURSES FOR METERMEN

Harold W. Kelley

INTRODUCTION

This presentation is not an attempt to prove the merits of on-the-job training. It has been firmly established that such training pays dividends to both the employer and employee. For a modest cost, the employer gets more efficient and better trained employees. The employee improves his educational and vocational status and becomes eligible for promotions and more important positions within his organization.

Specialized technical training can be a serious problem for small concerns. The lack of sufficiently trained supervisory personnel to handle the instruction will generally cause management to seek some form of outside assistance. The solution reached in the training of technicians for installation and servicing of watthour meters is an ideal example that can be applied to other types of technical training.

GENERAL

Practically every method of personnel training has been employed in teaching metermen the practical and theoretical aspects of their trade. Some of these methods and the results are as follows:

1. Use supervisory personnel as instructors and conduct the training wholly within the organization. This method has the advantage of permitting the training to be scheduled to properly suit the work load. In small organizations there is difficulty in getting properly trained instructors and a tendency to keep putting off the training to a more appropriate future date. In all organizations the great danger is a form of "in-breeding". If all training is done within the organization, there is little interchange of knowledge with others in the same business. This tends to create narrow views on basic problems and can result in excessive operating expenses or reduced quality of service.

2. Employ expert consultants to conduct the training. This method is generally limited in use because it is expensive. Additional time of supervisory personnel is sometimes required to orient the consultants to certain internal policies and practices and the reasons these must be followed in the instruction.

3. Permit manufacturers' representatives to conduct the training. This method can be employed with low initial expense. Meter specialists representing the manufacturers are recognized experts on metering and metering problems. They are competent to handle the special training courses prepared by their home offices and are able to answer questions outside the scope of the course material. It must be kept in mind that this type of training is not sufficient to provide a meterman with balanced instruction. These training courses should be supplemented by other types of training.

4. <u>Send the meterman to the manufacturers' factories to special schools.</u> Where such schools are conducted, the instruction is excellent in both theory and practical application. However, the detailed mechanical instruction will generally be limited to meters of that company's manufacture. The student will learn to appreciate the precision of manufacturing processes and factory calibration. This type of training is best used to give the meterman a change of scene and broaden his scope and appreciation of his job.

5. <u>Combine with other organizations in the area to conduct training on a workshop basis.</u> The workshop may be called a baby meter school. It provides excellent training in theory and practical application. As student groups are small, the individual meterman is able to bring out his personal problems and join in the discussions. Manufacturers often send meter specialists to these meetings to assist in the program and answer questions on their products. The workshop offers practically all the training facilities of a meter school. The level of instruction is generally set to provide maximum information to student metermen. Meter schools, because of larger and more diversified enrollment, provide special courses for meter engineers and management as well as for the student metermen. Workshop courses are organized and run on a "one shot" basis and are not scheduled annually as are meter schools.

6. <u>Send the meterman to a university or college sponsored meter school.</u> This method has become a standard for all organizations in the electric transmission and distribution business. The extension division of a college or university cooperates with the school's electrical engineering department to provide a yearly scheduled short course on metering. The course varies from three to five days in duration. Basic instruction in electrical theory is provided by the instructors from the electrical engineering department. Instruction in trouble shooting, servicing techniques, and equipment application is provided by engineers from the participating power companies, municipals, cooperatives, and manufacturers. Courses of instruction usually fall into two or three levels: Course A is for elementary single-phase instruction; Course B is for advanced single-phase and polyphase instruction; Course C (where provided) is for meter engineers, managers and superintendents. Manufacturers provide exhibits of metering equipment and accessories, featuring the newest devices available to the industry. Registration fees are nominal as instructors and classroom facilities are furnished by the school. The fees cover the cost of printing the programs and announcements, instruction materials and mailing costs. The student pays his own expenses while attending the school.

<u>ESTABLISHED TRAINING FACILITIES</u>

<u>A. Manufacturers</u>

<u>Duncan Electric Company, Lafayette, Indiana:</u> This company offers short factory

training courses. They consist of lectures on practical metering problems and actual testing and repair of the various types of watthour meters. Included in the course is a complete tour of the plant to show the methods of fabrication, assembly and calibration of meters. There are two three-day courses,- one for single-phase meters and one for polyphase meters. They are generally not run consecutively as students are not in a position to absorb both types of instruction in so short a time. The manufacturer has no charge for the instruction. While attending the course, the student pays for his own room and meals. As the instruction requires the full time of one engineer, the company prefers to have a minimum of 5 or 6 and a maximum of 20 to 25 students at one time. Those interested in taking the courses should inquire of the local Duncan representative or write directly to the factory for full details.

General Electric Company, Meter Department, Somersworth, New Hampshire: This company also offers a short factory training course. It consists of the history of metering, electrical fundamentals, practical application of meters and demand meters and testing and repair of the various types of meters. A factory inspection tour is coordinated with the training phase to permit the students to view actual practices that have been covered in the classroom. The school does not have a fixed curriculum. The needs and desires of the students are used to determine the program content. Even the length of the course is flexible. The time may vary from two to four days, depending on the background and previous training of the students. The number of students should be between 5 and 25 for any one course. As to be expected, there is no charge for the instruction and the student pays his own expenses while taking the course.

The General Electric Company realizes the difficulty students have in making the trip to Somersworth, New Hampshire because of its extreme northeastern location. This is one reason the company has made available a special Single-Phase Watthour Meter Training Course that is given by the company's meter specialists in the various sales areas. The course is designed to be presented to groups of 8 to 14 students. A student group may consist of REA borrower, municipal and power company personnel. The courses will be given at any location that is convenient to the student group. The time required is generally one and a half to two days. The course covers essentially the same instruction offered at the factory and employs all modern educational aids such as film strips, flip charts, motion pictures, demonstration instruments and cut-away samples of the devices being studied.

General Electric also has under preparation a similar training course for polyphase meters. This is expected to be made available to the meter specialists during the current year. Any REA borrowers wishing to utilize these courses should make arrangements through the local meter specialist of the General Electric Company or correspond directly with the company at Somersworth, New Hampshire.

Sangamo Electric Company, Springfield, Illinois: This company also offers a factory training course. There is no definite schedule for such courses. Requests are received from time to time from individuals interested in the training. After some 15 or 20 such requests are accumulated, the individuals are questioned as to a suitable date. From this procedure, the manufacturer obtains a class of from 8 to 12 students. As with other manufacturers, the course is without charge and covers the history of metering, electrical fundamentals, meter components, practical application, testing and repair of the various types of meters. The factory inspection trips are coordinated with the instruction. Production line fabrication, assembly, testing and calibration methods are explained by the instructor. The student pays

his own expenses while attending the courses. For additional information and probable starting dates for the courses, the prospective student should discuss the matter with the local Sangamo meter specialist and correspond directly with the company at Springfield, Illinois.

Westinghouse Electric Corporation, Meter Division, Raleigh, North Carolina: This company recently moved its manufacturing operations from Newark, New Jersey to the present location in Raleigh, North Carolina. Since this move, the company has not conducted a factory training course. In the future, the company plans to offer an extension type of correspondence course. As the Westinghouse Extension Course on Metering of Alternating Current (Course 10) was for many years a standard textbook and reference on metering problems, it is expected that this publication will be modernized and expanded to become the basis for the proposed correspondence training series.

B. University Sponsored Meter Schools

The following tabulation of meter schools does not include all schools conducted in the United States. As some universities schedule short courses on an erratic or "on demand" basis, it has been impossible to keep a complete listing. Those listed below are normally scheduled annually during the months indicated.

The formulation of each meter school program requires considerable time and effort. Topics must be selected and arranged in proper order for each instructional group. Proposed program speakers, other than university staff, must be contacted to determine if they can appear on the program. As the majority of the university sponsored meter schools are under the operation of the extension division where personnel are not versed in details of such a technical program, someone must take the responsibility of coordinating the entire activity. The university professor who handles the meter school will generally arrange to have a program planning committee comprised of utility engineers and manufacturers' representatives. This planning committee will meet with the university professor several months prior to the meter school, plan the program, make necessary arrangements with the speakers, and prepare ready for printing and distribution the detailed program. This has been a very satisfactory arrangement as the university gets the job done and the utilities get the type of program they wish.

School	Month Given	For Additional Information Correspond With:
University of Arkansas Fayetteville, Arkansas	October	Guy W. Berry, Head Department of Adult Education Division of General Extension University of Arkansas Fayetteville, Arkansas
University of Denver Denver, Colorado	March	Arlie E. Paige, Head Department of Electrical Engineering University of Denver Denver, Colorado
University of Florida Gainesville, Florida	April	Edward F. Smith, Electrical Engineering Department University of Florida Gainesville, Florida

School	Month Given	For Additional Information Correspond With:
Kansas State College Manhattan, Kansas	May	Roman J. Verhaalen Division of College Extension Office of General Extension Kansas State College Manhattan, Kansas
Michigan State University East Lansing, Michigan	September	Ira B. Baccus, Head Electrical Engineering Department Michigan State University East Lansing, Michigan
Mississippi State College State College, Mississippi	July	Harry R. Simrall, Head Electrical Engineering Department Mississippi State College State College, Mississippi
University of Nebraska Lincoln, Nebraska	January	R. W. Mills Supervisor of Institutes University Extension Division University of Nebraska Lincoln 8, Nebraska
North Carolina State College Raleigh, North Carolina Meter School Held at: Morehead City, North Carolina	June	Edward R. Ruggles, Director Division of College Extension North Carolina State College P. O. Box 5125, State College Station Raleigh, North Carolina
Oregon State College Corvallis, Oregon	September	Department of Electrical Engineering Oregon State College Corvallis, Oregon
South Dakota School of Mines and Technology Rapid City, South Dakota	August	Don R. Macken Director of Extension South Dakota School of Mines and Technology Rapid City, South Dakota
South Dakota State College Brookings, South Dakota	June	Department of Electrical Engineering South Dakota State College Brookings, South Dakota
Texas Agricultural and Mechanical College College Station, Texas	November	Department of Electrical Engineering Texas Agricultural and Mechanical College College Station, Texas
University of Tennessee Knoxville, Tennessee	March - April	Roy F. Center, Jr., Coordinator of Conferences Division of University Extension University of Tennessee Knoxville, Tennessee

School	Month Given	For Additional Information Correspond With:
University of Wisconsin Madison, Wisconsin	January	Ralph D. Smith Institute Coordinator University Extension Division Department of Electrical Engineering University of Wisconsin Madison, Wisconsin

DISCUSSION

Management has a serious obligation prior to using any of the technical training methods for metermen. It must select individuals suited both intellectually and tempermentally to absorb the instruction and perform the duties of the position. It has been said that a meterman should have the intelligence and education of a college professor, the patience of Job, the dexterity of a one-armed paper hanger and the personality of a used car salesman. It would also help if he were the life-long friend of all dogs. For some reason, few individuals with all these characteristics ask for jobs as metermen. The least that can be expected is to find someone with a grammar school education, interested in meter repair, calibration and application and tempermentally suited to working with small precision parts. In the rural cooperative type of utility, the metermen are often the front line of contact with the public. Their attitudes and personalities may largely determine the consumers' feelings toward the cooperative. It is important that management selects the correct individuals for this work, trains them properly, and offers enough incentive for them to stay interested in their work.

CONCLUSIONS

To properly train a meterman, or any other technician, one must give him a balanced program. It requires a certain amount of basic training to develop a man to an acceptable degree of proficiency. He must then be given refresher courses to keep him at that level. A beginner in this work should have some knowledge of metering before attending a university sponsored meter school. There are two acceptable ways this can be done: Arrange for him to work for a reasonable period with an experienced meterman; or, arrange for him to get individual instruction by attending a workshop type course, locally sponsored and with the assistance of the manufacturers' meter specialists.

The above suggestion is not an implication that university sponsored meter schools are not suitable for basic instruction. The truth is simply this: With registrations of from 100 to 200 students there are insufficient instructors and equipment to permit individual instruction and guidance of each student. Mechanical instruction in the parts, assembly, adjustments, and calibration of watthour meters should be done with one instructor to no more than six students. The ideal ratio is one instructor to two students. This is impracticable in a large meter school. Some schools have attempted to arrange facilities and instructors for this training. The results have been unfavorable to such an extent that most schools have reduced the mechanical instruction to lecture type sessions covering the subject generally.

A combination of workshop training, work with experienced metermen and attendance at university sponsored meter schools can change an inexperienced employee into a capable meterman. In addition to the technical training he obtains, he becomes acquainted with many other people in the same type of work. These friendships are of great value. Whether they be utility employees or manufacturers' meter specialists, they are generally willing to assist with difficult metering problems.

The procedures established for training metermen can be utilized in other technical training programs. Universities are pleased to establish short courses on technical subjects. Training sessions on oil circuit reclosers, radio and television interference, regulators, transformer design and application are all possible short course material.

PUBLICATIONS RECOMMENDED FOR HOME STUDY AND REFERENCE

Mathematics for Electricians and Radiomen by Nelson M. Cooke
Price: $5.50
Published by: McGraw-Hill Book Company, Inc.
New York, New York

Electrical Metermen's Handbook, Publication R-12, Sixth Edition
Price: $4.90
Published by: Edison Electric Institute
420 Lexington Avenue
New York 17, New York

Vector Representation for Electrical Metermen by D. F. Canfield
Price: $1.75
Published by: D. T. Canfield
Associate Professor of Electrical Engineering
Purdue University
West Lafayette, Indiana

Understanding Vectors and Phase by Rider and Uslan
Price: $1.00
Published by: John F. Rider Publisher, Inc.
404 Fourth Avenue
New York 16, New York

Construction of the Wattmeter Vector by J. C. McPherson
Price: $0.50
Published by: J. Richards, Publisher
Corpus Christi, Texas

Related REA Bulletins:
- 161-12, "Application Guide for Watthour Meters"
- 161-11, "Watthour Meter Maintenance"
- 161-20, "Transformer Problems"
- 161-10, "Uprating of Single-Phase Watthour Meters"
- 161-11, "Operation & Maintenance Records for Distribution Equipment"

TRAINING PROGRAMS FOR UTILITIES

By H. R. Hill
Westinghouse Electric Corporation

For Presentation at the 1957 Technical
Conference for REA Field Engineers,
New Orleans, Louisiana, January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

TRAINING PROGRAMS FOR UTILITIES

H. R. Hill

Two of the many training programs offered by Westinghouse to electric utilities are; first, the Regulator Training Program, and second, the Lightning Protection Training Program.

The purpose of the programs is to acquaint utility personnel in the basic engineering facts involved in the products, their applications and correct usage.

Our training programs have two basic objectives: first, to train and acquaint operating personnel with the importance of keeping their consumers supplied with uninterrupted maintained voltage throughout their systems; and second, to assist management in doing a better job at present and to meet the demands and problems of tomorrow's expanding market.

VOLTAGE REGULATOR TRAINING PROGRAM

The Voltage Regulator Training Program progresses from the basic fundamentals of electricity to the construction and application of regulators and finally, to practical regulator installation problems which the students solve themselves. It's a complete package that includes every device to help utilities do a better, faster training job. The students learn both by instruction and by doing.

The Devices Used

The devices that are used in carrying out this program include:

1. A two-part motion picture.

2. Slides.

3. Wall Charts.

4. Demonstration Kit.

5. Lectures and Meeting Guides.

6. Study Manuals.

The first of the devices, the two-part motion picture, "How Voltage Regulators Are Made", is an interesting presentation of the how and why of voltage regulator construction, related to the job that the regulator must do. The film is divided into two sections in order that it might fit conveniently into the meeting schedule.

The slides, projection slides in full color, add visual impact to the important points, illustrate involved statements with simple picture stories and occasionally inject a light touch to keep interest high.

The wall charts are used for details that can "take" the broad treatment of chart techniques and for items that must be referred to repeatedly -- such as diagrams of circuits and systems. The charts measure 35 inches by 46 inches.

The demonstration kit furnished with the course includes actual working models of regulators and control equipment. These models not only show how regulators work and their effect on a simulated distribution system, but they also help students understand the basic principles of alternating current transformation.

The kit includes: a distribution line test panel, induction regulator with control relay, bypass switch and voltage regulating relay. A split-type core and interchangeable coils for connecting the test panel are also supplied.

The lessons and meeting guides that have been prepared for each of the six lessons are complete, authentic and accurate. They have been prepared by Westinghouse engineers working in conjunction with utility engineers and a trained industrial instructor. A detailed script is provided the instructor. It comes with an outline designed to keep his lectures moving on course. If the instructor wishes, he may read directly from the script. A 3-ring binder is furnished with each set of meeting guides.

A complete set of six study manuals is supplied to each student. These books are well illustrated with prints from the movies, slides and charts and each book contains a quiz section to help the student evaluate his progress. A binder is supplied with each complete set of study manuals.

Index to the lessons (each lesson is of approximately 1-1/2 hours duration.)

Lesson 1 considers basic theories and principles: a review of basic electrical principles; a review of distribution systems; and a review of principles of voltage transformation.

Lesson 2 considers the principles of regulator operation: the operating principles of step regulators; and the operating principles of induction regulators.

Lesson 3 considers regulator construction and assembly: single-phase pole-type step regulators -- the exterior parts; single-phase pole-type step regulators -- interior parts; correlation of step regulator components; description and inspection of tap changer mechanism; and station-type regulators, single-and three-phase.

(At this point, and as a part of Lesson 3, part 1 of the motion picture "How Regulators Are Made" is shown. The first part of the film is devoted to step regulators.)

Lesson 3 continues -- following the showing of the first part of the motion picture with: induction regulators, exterior and interior parts.

(At this point, again as a part of Lesson 3, part II of "How Voltage Regulators Are Made" is shown. This part of the film considers induction regulators.)

Lesson 4 considers control systems: the basic function of control systems; operation of the voltage regulating relay; operation of time delay relays; voltage regulating relay; and motor controls.

Lesson 5 considers connections: the types of a-c distribution systems; types of connections; connecting single-phase regulators; and connecting three-phase regulators.

Lesson 6 considers installation and maintenance of regulators; Installations; maintenance; and safety.

This is the first of the two programs, then. As can be seen, it's designed to make the workings of one of the more important parts of a distribution system a bit more clear. It has been successful, and it's been used frequently.

LIGHTNING ARRESTER TRAINING PROGRAM

The second of the two training programs under consideration here is called "Power to Protect". It's designed to familiarize personnel with the Westinghouse line of lightning arresters.

The program is an outgrowth of the many requests Westinghouse has received for material to use in employee training programs. (This is the case, of course, in the Regulator Training Program, too.) Westinghouse provides all of the materials needed to conduct the course.

The Devices Used

The devices used in carrying out this program include:

1. Three color movies.

2. Flip Charts.

3. Westinghouse literature,

4. Instructor's Guides.

5. Students Manuals.

The first of the three color motion pictures is titled "Power to Protect". It traces the history of mankind's struggle to protect property from lightning damage, from the time when bells were rung during storms up through the most modern types of arrester gear.

The second movie -- "Protection Assured" -- shows how a lightning arrester is manufactured by Westinghouse. Filmed in a Westinghouse plant, this film shows the step-by-step construction of the arrester.

The third movie -- "Traveling Waves" -- is designed to make a relatively complex subject more clear and easy to understand. The film uses a wave analog machine to illustrate the phenomenon of disturbances of transmission lines.

The flip charts illustrate important points from the seminars. They measure 16 inches by 20 inches and are contained in a binder that opens to form a handy desk-top easel. The charts are for the instructor's use.

Copies of pertinent Westinghouse literature describing the features of the company's lightning arresters may be obtained and used as a part of the program. The literature usually consists of catalog pieces.

The instructor's guides contain complete information for running the seminars.

The student manual consists of four printed lessons -- called seminars -- and is given to each student.

The seminars proper are divided into sections. The first seminar is divided into four sections: The first considers the nature of lightning; the second, the effects of lightning on power systems; the third, lightning protection devices; and the fourth, applications of lightning arresters.

The second seminar is divided into two parts. The first considers traveling waves; the second, lightning protection of distribution circuits -- other than substations.

The third seminar is divided into two parts. The first considers lightning protection of substations; the second, lightning protection of distribution circuits -- other than substations.

The fourth seminar is divided into three parts. The first considers protection of rotating a-c machinery; the second, protection of Dry-Type transformers; and the third, protection of metal-clad switchgear.

So far as programming is concerned, the seminars should be spaced out to allow time for assimilation of the material. Each session is two hours long, and the Westinghouse Consulting and Application Engineer makes all the arrangements and conducts the course.

It is suggested that the utility appoint a group leader for the class. The group leader can arrange for necessary equipment, prepare the location for each seminar, make sure of maximum attendance, and so on. In working closely with the Westinghouse instructor, this group leader would be prepared to give the entire course to a new group in the future.

The point made at the beginning of this paper applies again: The basic purpose of the Lightning Arrester seminars is to present to electric utility engineers a complete graduate training course in lightning protection, with particular emphasis on lightning arresters.

This program is highly technical in nature. At the same time, it is as comprehensive a package of information on the subject of lightning protection as is available anywhere. Data has been gathered from literally hundreds of sources and, of course, from years of original Westinghouse investigation.

The course is a service. It's designed to share with the utilities the knowledge of lightning effects on electrical systems acquired through years of research. Utilities benefit from the course because it gives employees the know-how they need to provide better system protection from lightning, reduce outages, improve customer relations and protect valuable equipment from damage.

The first hour and one-half of each meeting is presented in lecture form by the Westinghouse District Consulting and Application Engineer; using movies, flip charts and literature as required. The final half-hour is devoted to open discussion.

Product Training Courses

As we pointed out at the beginning, the programs detailed are only two of many. Westinghouse makes available Product Training courses such as those for outdoor distribution apparatus and lighting. This series of courses is directed, primarily, at the sales force handling the items that constitute the product line. It comprises a consideration of such types as: basic electricity, principles of outdoor distribution systems, substation basics and application, transformer principles and design, reclosers, sectionalizers, cutouts, coordination of reclosers, sectionalizers and cutouts, lighting, capicators, regulators and meters.

AN APPROACH TO LONG RANGE SYSTEM PLANNING FOR RURAL ELECTRIC DISTRIBUTION

By Harry Dewar
Patterson & Dewar Engineers
Decatur, Georgia

For Presentation at the 1957 Technical
Conference for REA Field Engineers
New Orleans, Louisiana, January 14 - 18, 1957

REA

U. S. DEPARTMENT OF AGRICULTURE

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R. G. Zook
Assistant Administrator

AN APPROACH TO LONG RANGE SYSTEM PLANNING FOR RURAL ELECTRIC DISTRIBUTION

Harry Dewar

A long range rural electric system plan is for use today!

Rural electric system planning in our time needs to be as continuous as electric service continuity and patterned to the conditions and needs of the individual area.

The long range rural electric system planner needs to recognize the three dimensional nature of electric distribution system economics.

One dimension is the year by year change in electric load and associated variable annual line loss cost.

A second dimension is the annual cost of the physical components of the electric plant, including interest on capital invested, depreciation, maintenance, replacement, taxes and similar items usually measured as a percentage of capital investment.

A third dimension is the national and local economy which varies the "constants" as of a particular time used in determining the first and second dimensions.

Electric system planning consists of application of engineering principles and economics in a rapidly changing electric industry. Rural electric system planning is a science but it does not have the exact mathematical relationships of basic science nor of many phases of engineering in manufacturing.

As suggested by the AIEE System Planning Subcommittee, electric system planning can be defined as "the process of determining when what facilities should be provided where in order to assure adequate electric service at minimum average annual cost to the community". Rural electric system planning involves the application of engineering principles, application of available materials and equipment and some development of new equipment, recognition of new scientific developments affecting electric distribution, all applied to serve at what standards, what number of families and businesses, who will be where, when and with what requirements for instantaneous electric power at minimum cost whenever there is the need!

Long range system planning for rural electric distribution is an integral part of system planning. It is a method of providing for use today, a long range objective and direction in order that plant additions can be made as required today in a manner to insure long range minimum annual cost to the community for electric power within the service standards established. In general this condition is furthered through a design that provides for load additions through plant additions without excessive initial expenditure in a manner that efficient use can be realized over the normal life of such additions.

THE CONTINUING NATURE OF SYSTEM PLANNING

A continuing appraisal of economic conditions in each rural area with respect to

change in population, in living standards, broad change in agricultural methods and in reforestation, the dispersal and expansion of industry, change in the wholesale cost of electric power, and possible need for change in service standards, stands at the heart of long range planning. These economic conditions have the major effect on the amount of electric load distributed and the overall cost of electric service.

The economic pattern in respective areas served by rural electric systems has the potential to change greatly over the next twenty-five years. The present increase in population in the United States and present indication of an accelerated rate of increase, the actual shift in population and the trend to greater shift away from some rural agricultural areas and toward semi-suburban areas have had and will have tremendous impact on system design. The extension of municipal city limits has affected many rural systems, particularly where the municipality also distributes electric power. The new long range U.S. Federal sponsored Inter-City Highway Program will have material effect on the population within the boundaries of many rural electric systems. Add to these factors the present exponential rate of increase in the use of electric power in many rural and semi-rural areas, the change in the value of the dollar over the past decade with only limited change in the cost per KWH, existing and projected new developments in the use of electricity both in the home and on the farm, the tendency to dispersal of industry, and the variables possible for insertion in the inert electrical formula are such that the need for carefully considered and continued analysis for the individual electric system and sub-area within the system are obvious.

For example, the economics of electric circuit loading resulting from the increase in cost of labor and materials and near a constant cost of electric power over the past six years, point to much heavier loads for a given circuit capacity. The potential for change in a particular area is emphasized by consideration now being given to establishment of a manufacturing plant in a reasonably isolated highland area dependent on establishment of an air field suitable for passengers and later for air freight.

There can be no security for the System Planning Engineer in electrical principles and two dimentional charts unless the nature of the factors which form the basis of the constants in the formula are maintained in proper perspective. Results from the correct solution of an equation are no better than the data inserted. The System Planning Engineer must assume a responsibility for the basic data used currently, in terms of a logical appraisal of available influencing factors. This means that the System Planning Engineer must necessarily be more than a technician.

The rural electric system planner is presented with the possibility of substantial load development over a much greater area than for city and suburban planning. Distribution system planning in urban and suburban areas often has the advantage of city development plans with regard to population changes, zoning for commercial and industrial areas and standards of individual residential construction within a given area. Based on proven need, the use of this type urban planning is increasing and gives good basis for urban long range electric system design.

During the past ten years many rural electric systems have changed almost totally in character, increasing in average KWH per residential consumer above 500%.

In addition, large blocks of commercial and large power load have developed in many rural areas. In contrast, many other systems and sections of the majority of systems have maintained an essentially rural character as known ten years ago with an average residential KWH increase of only 150% to 200%.

A "here today only, practical mind" can dismiss long range system planning as being impractical and take a "wait 'till we get there" approach. However, the true value of the long range plan is derived from its use in making decisions today that can have material effect on the character and cost of electric service in the future. Industry wide estimates project a doubling of present electric power demands within seven to ten years, with possible quadrupling or greater increase resulting within fifteen to twenty-five years. Certain rural electric systems already are "there" and beyond in terms of the probable fifteen to twenty-five year load growth for other rural systems. Experience locally as well as in the whole electric industry points to the probability that existing load will multiply several times again within the next fifteen to twenty-five years even in these areas of above average rural electric use.

In spite of present difference in electric power rates over the country it is probable that areas of like economic resources and conditions will eventually have similar electric power requirements. For this reason, design trends in areas of above average density are pertinent to other areas of similar basic potential.

Whether the rate of change has been fast or slow, the sound economic benefits of system planning over the past ten years have been established. The wide latitude for change indicated for the future makes further development of the science of long range planning imperative.

THREE FUNDAMENTALS OF LONG RANGE PLANNING

At least three fundamental determinations must be made in long range system planning. First, an estimate of the general location, size and character of electric load to be served in the future. For long range planning purposes the approximate time at which the estimated major increments of load will be realized is of importance primarily with respect to the normal life expectancy of major increments of electric plant additions.

Second, determination of the type of electric distribution system to be maintained with respect to such factors as service reliability, voltage regulation, availability of three phase service and grade of construction.

Third, the design of the most economical system in terms of the lowest annual cost over the years to serve the loads estimated at the service standard determined.

The first item may be the most difficult to determine. A change in cost of labor and materials, and in the cost of electric power at wholesale and retail can affect the first two items. A change in the standard of service can be required by reason of further dependence on electric power. These variables are such that the planning of all three items must be kept fluid from year to year.

THE LONG RANGE PLAN OBJECTIVE

Long range rural electric distribution planning needs to be recognized as a guide to relate long range requirements to present actions - and be recognized only as a guide. The long range plan gives an objective and points a direction for use in determining the character of plant additions needed today.

In long range planning, consideration can be given to the principal features and physical components of the future electric plant to serve the loads estimated in the respective areas of the system such as service standards, the choice of distribution voltage, substation locations, transmission line requirements, typical distribution feeder size and degree of loading, system sectionalizing requirements, number of circuits into respective areas, the relationship of the major components of the existing plant to future requirements, the need for development of new methods and equipment, and long range capital and annual cost. Consideration can also be given to the characteristics of the people and probable use for the soil, and to principal geographical features with respect to electric plant location such as mountains, valleys, lakes, cities and towns and principal rivers.

The details of future electric circuit construction with respect to existing roads and specific routings cannot be forecast in detail. Within twenty years many new roads will replace or supplement those of today. Correspondingly, except for determination of the characteristics of a typical circuit with respect to service standards, detail engineering analysis of future voltage regulation and the like is not justified. However, the overall future need in terms of size and capacity of building units for today's need that will also be practical for continued use in the future can be determined.

The Planning Engineer must be able to develop practical and economic steps in terms of principal electric plant components for a transition from the existing electric system toward the future design as electric load growth dictates the need.

In evaluating the future design character, a load estimate of approximately twenty-five years can be of more value than one of ten years. Emphasis can be placed on estimated future load without regard to the specific year when such load may be realized. The schedule for new plant can be based on the size and character of the load to be served, and the time for construction can be determined by actual load growth.

The long range plan can be re-analysed each year and maintained as a guide.

YEAR BY YEAR CAPACITY REQUIREMENTS

Calibrated by the long range guide, the engineer can return to the present day with feet planted firmly on existing facts and conditions for determination of the current year's need, if any, for additional plant capacity. Electrical measurements on the system and specific electric load to be added should be used to determine this need.

Maintain a long range guide but use the existing plant without major additions to serve load growth for as long as practical. Delay in installation of major plant

additions can result in selection of a design to give the better long term economics.

TRANSMISSION AND SUBSTATIONS

In long range planning, potential distribution substation locations must be determined geographically with respect to the distribution voltage considered and in many cases without regard to existing load density. To a great extent the long range electric load estimated must be based on the potential of individual areas.

Cross country transmission lines between urban and industrial areas have provided a number of real and potential sources of power for rural distribution in the southeast. All available long range plans for future transmission lines can be considered in determining potential future substation areas. Knowledge by the transmission agency of the long range rural need often has influenced the choice of routing for new transmission line. The coordination of transmission and rural distribution is a prime function of long range planning, whether one or more agencies is involved.

Recognition can be given to the overall cost with respect to both transmission and distribution, probable service conditions that may result and limits in quantity of power available in the future at a particular location. This does not preclude the use of distribution centers for interim periods from nominal capacity sources. There are such locations where the capacity of the source will be increased as load growth requires, or where the source can be abandoned later without loss of appreciable capital investment by the rural distribution agency. However, advantage gained by the rural electric system in sectionalizing, service continuity and potential for continued use of facilities constructed from the distribution center often weigh heavily in favor of establishment of distribution centers from substations located directly off transmission lines of potential capacity to serve the foreseeable needs of the distributor.

Transmission has been constructed for initial operation at the distribution voltage where a long term annual dollar saving to the distribution system was indicated. This approach can be used successfully, especially where distribution circuit capacity between two areas will be reduced materially after installation of a second substation in the future.

DISTRIBUTION FEEDER CIRCUITS

New or rebuilt feeders out the first few miles from the distribution substation can be planned of a conductivity within the range of the so-called maximum economical conductor for use on rural electric distribution. Present costs and conductor characteristics indicate that Number 2 through Number 2/0 conductivity generally is the largest economic range for conductors for strictly rural electric distribution.

This policy can mean a capital expenditure in a new feeder unit above immediate need. There will be locations where the new feeder unit can be loaded further initially through serving an area greater than planned for the future design, thereby delaying other new plant construction. New circuits extending into an area toward a probable future substation may be constructed with the large conductor on into the immediate

area of the future distribution center, dependent on the apparent schedule for installation of the second substation. New maximum size rural circuits extended into the outer area of the project boundary or in the areas of geographical limitations, such as mountains and large rivers, may be decreased in conductivity as the circuit extends from the substation in relation to the decrease in total loads distributed over the feeder.

Maximum delay in new feeder circuit construction, consistent with good service standards will save in overall cost and permit time to gain as much data as possible to insure a more practical installation when the new additions are constructed. Often new construction can be delayed through greater use of existing feeders to their full economic limit with application regulators and capacitors, and through the construction of tie lines.

Where new rural circuits are constructed in the range of maximum conductivity for rural lines, future load growth beyond the capacity of the feeder can be handled with construction of additional circuits or by increase in below maximum capacity of existing circuits or by the addition of new distribution substation areas. Through such a procedure, new distribution substation areas and associated transmission required, and new distribution feeders are added in the form of reasonably standard building blocks as the actual load density requires increased capacity.

LINE VOLTAGE REGULATORS

With increase in the use of electricity in rural areas for the past ten years, major investment has been needed to increase the capacity and maintain service standards. Due to the distance involved on a rural electric system and the large variation in load normally experienced over a twenty-four hour period, the economics of rural electric distribution make it necessary that the voltage from the substation be boosted to an approximately 127 volt base during peak load periods in order that the voltage further out on the circuits can be maintained within the minimum limit. It is also desirable to reduce the voltage during light load periods from the substation in order to limit system losses and excessive depreciation of customer equipment.

The economic distribution distances for circuits in the 12 KV class and the economics of maximum conductor size support the use of line voltage regulators located out on certain of the longer distribution feeders at a distance where the voltage at peak load may be down to some 118 volts. These line voltage regulators, acting through the line drop compensators, boost the output during the peak period back to the approximately 127 volt base to keep within the minimum voltage limit at the end of the circuit. This characteristic of voltage variation and need to compensate for voltage variation on a rural electric distribution feeder is such that the substation and line regulators can become an integral part of many distribution feeders.

Within the limit of service standards and economics for lowest annual cost, arbitrary limits should not be imposed on use of line voltage regulators.

CAPACITORS

In the future it is estimated that capacitors will be used extensively on rural electric distribution.

On a majority of rural electric systems the magnitude of reactive power on individual circuits has been too small to permit installation of capacitor banks of an economic size. On certain rural systems the increased load, the increase in off peak load and more extensive use of electric motors give an appreciable block of reactive power throughout the twenty-four hours on individual circuits. In such cases fixed shunt capacitors have been installed to economic advantage.

Capacitors can be applied based on a recording of kvars. Depending on the electric wholesale power rate it is possible to save cost through the application of individual capacitor banks of a size to result in a leading power factor during short periods of light load. This permits the installation at lower unit cost and permits a margin for continued increase in kvars.

Banks of switched capacitors will be used in special applications for seasonal loads.

CONVERSION OR A NEW FEEDER

True to the whole approach in rural electric distribution system planning, the choice between converting an existing multiphased feeder of moderate capacity to a feeder of maximum rural line capacity as compared with the construction of a new maximum capacity feeder and retention of the existing multiphased unit is not an exact science and must be determined for the specific case in question. The lowest annual cost which may be indicated through conversion of the existing line, can be weighed against operating flexibility, service continuity, projected future growth and rate of growth, ability of the individual system to pay the cost of operation, and the availability of right-of-way easements for a second circuit. The matter of right-of-way easements alone often dictates the decision.

Chart No. 1 compares the total annual cost of conversion from existing three phase Number 4 ACSR to higher conductivity for various loads in terms of annual cost for capital, maintenance, depreciation and line loss cost as determined from the REA Bulletin 60-4. Curve B is the same as Curve A but with the annual line loss cost taken at 60% of the loss experienced with the circuit peak KW occurring regularly each month during the twelve months of the year. This annual loss correction factor for Curve B is set to account for a circuit carrying a widely varying system demand over the twelve month period such as is experienced in certain irrigation areas in the summer and in certain concentrated electric house heating areas in the winter. For a specific substation area, this annual loss correction factor, based on the substation peak for each of the twelve months, is taken as:

$$\text{Factor} = \frac{(KW_1)^2 \quad \text{plus} \quad (KW_2)^2 \quad \text{----------} \text{ plus } (KW_{12})^2}{12\ (KW\ \text{max.})^2}$$

The system peak KW used with the curve in Chart 1 can represent an existing steady peak that would continue on the given circuit indefinitely, or, as is usually the case, this system peak can represent an effective peak over the years, starting from a nominal existing load and running beyond the effective or RMS peak. The effective or design load

can be represented by:

$$KW_{RMS} = KWP \sqrt{\frac{A^2 - 1}{Log_e (A)^2}} \quad *$$

Where: KWRMS = Effective load on the circuit over the years considered.
KWP = Present KW demand on the circuit.
KWF = The KW demand on circuit estimated for the future.

$$A = \frac{KWF}{KWP}$$

* (As developed in the paper by Mr. Roland W. Schlie presented in the REA Technical Conference for Field Engineers in St. Louis, Missouri, in January 1956.)

The cost of conversion of an existing line, compared with the cost for construction of a new line and retention of the existing line is analysed in Table 1. As detailed in this table, conversion of the existing feeder involves the retirement of capital investment on which payment for the capital funds used for the original investment must still be continued. The capital investment retired is offset up to the amount of the salvage value. In addition, there is the labor cost of retiring the original investment. In this example, no recognition is given to a depreciated value of the existing line, it being assumed that the plant is maintained in good condition. The analysis is also made without regard to the particular method used in handling reserve for depreciation.

The choice of conversion or construction of an entirely new feeder and retention of the old is similar to the matter of a trade-in of a used truck of moderate capacity on which monthly payments are still due for a larger unit, as compared with retaining the old truck and purchasing a new and larger one. There is the cost of maintaining and operating two units weighed against the advantage of greater flexibility, service potential and capacity in two units. The choice can lie in the traffic density and the amount of flexibility that the business can afford.

Where right-of-way is available and the existing revenue and potential for growth of electric load in a given area permit, the choice can be for the second feeder in lieu of conversion. An additional feeder can provide three phase service over a wider area and can increase service reliability during construction, maintenance and emergencies.

Although difficult to evaluate in specific dollar value, there is much evidence that increased service reliability builds electric load and can result in lower cost per KWH distributed.

LONG RANGE PLANNING APPROACH ON A SPECIFIC PROJECT

On this project the Planning Engineer proposes to work with the distribution system Manager, the Directors, the large local industry, civic, agricultural and business leaders, the representatives of the REA, the generation and transmission agency and similar representatives to estimate the potential long range growth of the

respective sections within the area. Electric load increase will be based on estimates of land use, industry, population and average KWH use for homes and small business.

This load estimate will be indicated geographically on the load diagram in relatively small unit areas, possibly of four square miles. The load diagram will indicate major geographical features, such as lakes and mountains. Details used in determining the load with respect to number of consumers and average KWH consumption and large power loads will be shown on work sheets only.

General service standards will be established with the electric system representatives. Consideration will be given existing standards and estimates of future requirements that may be imposed with increased dependence on electric service in the future.

The load diagram and service standards will be reviewed and agreed upon with the Owner.

Determination will be made of the optimum location of substations for respective distribution voltages, using methods that will permit easy movements on the map of possible distribution centers and areas covered for trial and error. Consideration will be given first to distribution centers without regard to existing power source or distribution facilities, and then to the economics for use of the existing facilities, and available plans reasonably established for future transmission and generation.

Decision will be made with respect to the optimum distribution feeder conductivity and load limit, the number of feeders, and the approximate areas served by individual feeders. Feeder routes will be located with respect to major geographical limitations.

General correlation will be made between new substations, transmission, and distribution feeders and the main components of the existing plant. Intermediate steps from the present to the future design will be given for the major additions with respect to increase in system load.

Cost estimates will be prepared for the major plant additions.

HEAVY CONDUCTOR IN URBAN AND SUBURBAN AREAS

In urban areas where electric power is used for residential space heating, use of conductor in the thousand circular mill sizes for sub-transmission and for feeder distribution circuits in the 12 KV class has increased. Control points limiting pole spacing and cost of conductor are such that stranded all aluminum cables are the economic choice.

Chart 2 shows the curves for loading all aluminum conductor compared to annual cost for capital. Line construction cost is assumed to vary approximately as the weight of the conductor.

There are rural electric distribution systems now serving heavy concentrations of load within one to four miles of existing prime substations. In certain locations, present development and future land requirements limit extension of transmission and

number of circuits from the substation and there is potential for continued load growth in the immediate area of several times the existing load. Consideration needs to be given the economic relationship between unit size of plant additions, the normal life expectancy of the additions, service standards, and the probable rate of load growth. Use of the heavier CM conductor is indicated in particular cases.

NEED FOR NEW EQUIPMENT

The need for new equipment keeps pace reasonably with the demands of electric customers, engineers and system operators. However, inherent need for a reasonably wide variation in voltage on a rural electric line due to the distances covered, emphasizes the need for continued improvement in the development of equipment less sensitive to voltage change. In recent years television sets have presented the principal problem. The newer television sets appear to be somewhat less sensitive to voltage variation and further improvement in this direction may be practical.

The great expansion just beginning in air conditioned homes makes imperative the assembling of air conditioning units with normal running power factor of about ninety per cent.

Although three phase oil circuit reclosers and oil circuit breakers may be used on principal feeders in the years ahead, more emphasis is needed toward sale of motor controls equipped to reduce damage from single-phasing.

On certain systems carrying heavy motor load, it is desirable to drop the motors off the line with the operation of oil circuit reclosers and breakers in order to limit the initial amperes on re-energizing the line. For irrigation pumps which may be unattended and where across-the-line restarting is practical due to line capacity and the low load starting characteristic of the irrigation load, satisfactory results have been obtained through the use of a variable time delay restarting relay in the range of zero to two minutes, energized from the distribution line. Further development in use of this principle can be considered where large blocks of low starting torque motor load are served.

The nature of certain larger capacity three phase oil circuit reclosers is such that operation of the small single-phased reclosers further out on the line causes operation of the heavier reclosers through the stage of the initial "fast" settings. On a circuit serving a sizeable area, this can result in excessive operation of the heavy recloser and multiple interruptions of service to three phase electric motors. As the fault currents, acting on the smaller reclosers out on the line, are reasonably limited in maximum value, consideration can be given by the manufacturer to a practical means of bypassing the fast operation of the large recloser for fault currents below a certain selected value.

VARYING METHODS GIVE GOOD RESULTS

Electric utilities, operating with good planning results in the same general area or comparable areas, often differ considerably in the choice of distribution and transmission voltage and substation practice. Within the realm of good logic for the

individual approach used, the fact that the approach varies can give the better overall answers to the whole industry.

NEW APPROACHES TO LONG RANGE SYSTEM PLANNING

Recent technical articles point to increased use of large scale computing machines in planning analysis for electric power generation, transmission and distribution. Initial use of the computers has been in the more complicated network generation and transmission systems. Large scale computer analysis of multiple factors on at least typical rural electric distribution systems with respect to current national economic directions as well as computations of system losses and capital plant economics undoubtedly will be developed in the years ahead. It is in the realm of practicability that such analysis will be used to improve overall efficiency of system planning through better integration of the economic and technical factors involved.

The Electric Engineering Division of the REA has made substantial contribution to the approach to system planning through study and coordination of experience on the more than one thousand rural electric systems. The analysis of statistics from these systems and the opportunity to review the rural electric planning studies from different engineers presents a most valuable source of basic data. Continuation of the work in progress can lead to further development of planning guides through economic comparisons of circuit length and loading and substation size for a given voltage and load density for typical systems, through studies of requirements for distribution transformers, and studies on comparison of service standards to annual cost.

Reference is made in the industry to the possible extensive use of the small solar or atomic power sources in the home at sometime, somewhere. The development of practical power sources that can compete economically with distribution of electric power from the central generating statio.. appears now to be more than fifty years in the future.

New developments in electrical equipment and in usages for electric power in the years ahead will need consideration as these new developments are known and can be evaluated.

CONCLUSIONS

Long range rural electric system planning is closely allied with national and local economic conditions and future economic directions.

Experience, existing conditions and local and national economic direction can be re-evaluated regularly to project future electric design needs as a guide in determining the character of construction needed for plant additions today. Such a yardstick of probable future need can be of great value in maintaining the lowest annual cost over the years within the service standards.

Major plant additions can be made as electrical measurements of the existing system dictate a need for increased capacity that cannot be met more economically with moderate rearrangement and additions to existing circuits. Maximum delay in

installation of major components can result in selection of a design to give the lower long term annual cost.

Through long range planning, sections of new plant capacity can be added as reasonably standard size building blocks, to provide for load additions through plant additions without excessive initial expenditure and in a manner that efficient use can be realized over the normal life of such additions.

Increased load density within the area of economic distribution from an individual substation can be met with the addition of new feeders. This can result in dual feeders being available to serve individual areas and potential for increase in service continuity during maintenance and emergencies. Improved service continuity can result in an increase in the ratio of revenue to cost.

Often new transmission, substations or distribution feeders can serve an alternate purpose or area initially and thereby delay other capital expenditure.

There is increasing contrast in the character of rural electric distribution systems, and wide variation in the system planning need on the individual systems. Rigid adherence to a uniform planning approach can result in decreased value to the individual electrical system, and can retard development and operation of varying long range plans needed over the industry to serve the increasing variety of problems incident to the substantial long range load growth forecast.

TABLE I

ANALYSIS OF FIXED ANNUAL COST OF CONVERSION (EXCLUSIVE OF LINE LOSS COST)

New Rural Line - Construction Cost

3ϕ 4 ACSR	\$2600/mile
3ϕ 1/0 ACSR	\$3545/mile

Conversion - Construction Cost

Type Conversion	Plant Additions	Plant Retired	Cost of Removal	Salvage
3ϕ 4 ACSR to 3ϕ 1/0 ACSR	\$2434	\$1210	\$403	\$620

Annual Costs

Interest & Amortization = 4% x Plant Investment

Maintenance, Operation, etc. = 4.5% x Plant Investment

Total Annual Cost = 8.5% x Plant Investment

Type of Cost	3ϕ 4 ACSR to 3ϕ 1/0 ACSR	3ϕ 4 ACSR + 3ϕ 1/0 ACSR	Remarks
Plant in Service	8.5% (Plant Additions + Existing Plant - Plant Retired) .085 (2434 + 2600-1210)= \$325	8.5% (Plant Addition + Existing Plant) .085 (3545 + 2600) = \$520	Continuous Cost
Labor Cost for Removal of Plant	4% (Cost of Removal) .04 (403) = \$16		Reduces to zero 35 yr. from date of conversion
Plant Retired	4% (Plant Retired) .04 (1210) = \$48		Reduces to zero 35 yr. from date of original installation
Salvage	4% (Salvage Value) .04 (620) = \$25		Credit against plant retired
Total Annual Cost	\$364	\$520	

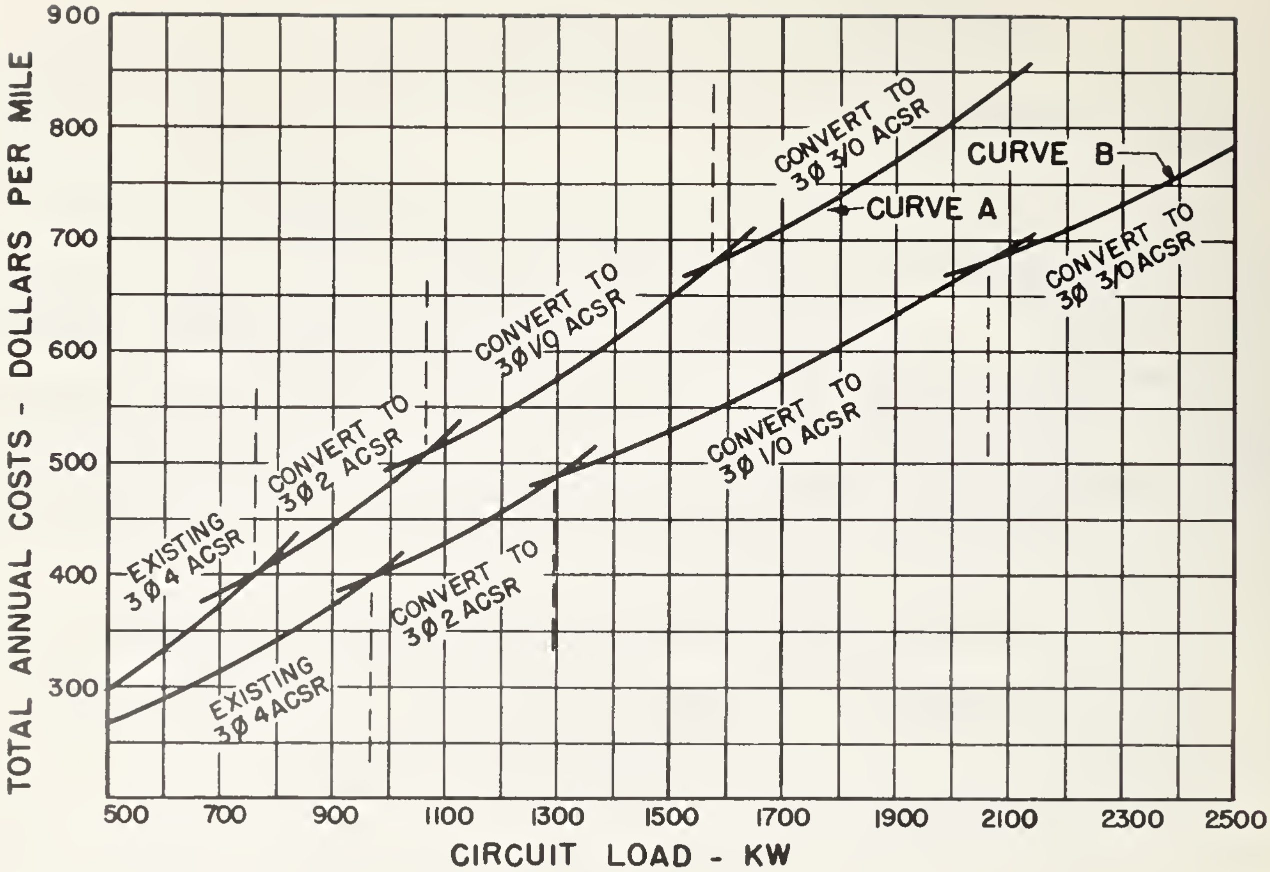

CHART NO. 1 ECONOMIC LOADING FOR CONVERSION OF 3Ø 4ACSR

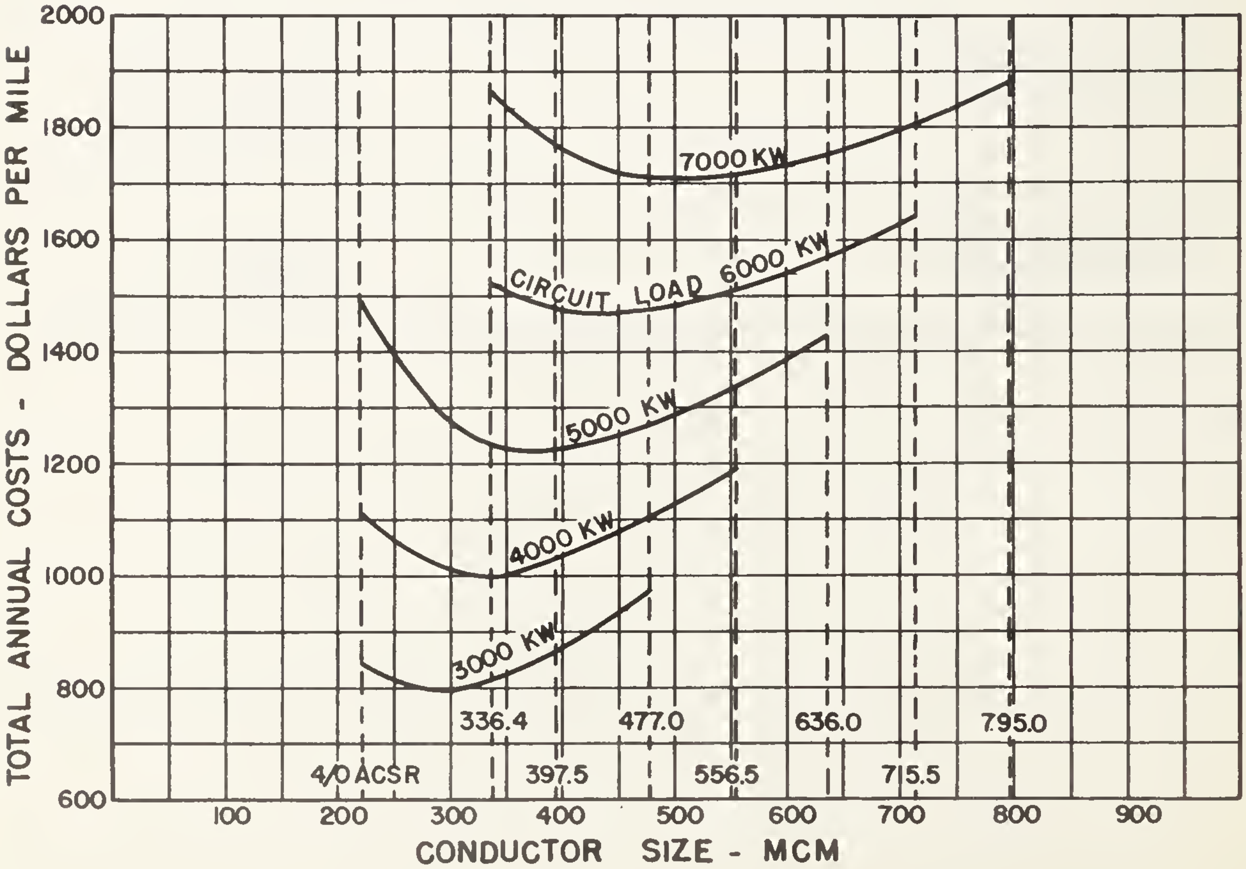

CHART NO. 2 ECONOMIC LOADING FOR HEAVY CONDUCTOR

EXPLORATORY RURAL SYSTEM DESIGNS AT HIGHER KWH LEVELS

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For Presentation at the 1957 Technical Conference for REA Field Engineers, New Orleans, Louisiana, January 14 - 18, 1957

REA

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

EXPLORATORY RURAL SYSTEM DESIGNS AT HIGHER KWH LEVELS

Thearl Essig Harry Thiesfeld

INTRODUCTION

Tremendous expansion in use of electric energy since World War II has frequently overshadowed attempts to maintain capabilities of rural electric systems at satisfactory levels.

Engineers and management of this segment of the industry realize more flexible methods of increasing system capability are necessary to cope with increases in demand, and maximum use must be made of existing facilities as well as economic planning of improvements if adequate operating margins in high power cost areas are to be maintained.

There is a definite need for:

1. Investigation of system designs at consumptions 200% to 500% of existing loads, or even higher.

2. More detailed investigation of capabilities of existing facilities.

3. More efficient approach to preparation of exploratory designs than cut and try methods.

Some pitfalls of design engineers:

1. Too imbued with extreme individualistic ideas on certain things.

2. Failure to practice a rational standardization.

3. Insufficient review by an engineer of broad overall experience.

4. Failure to use and evaluate the accounting system standards for economic comparisons.

Rural electric systems from the viewpoint of REA may involve either distribution or transmission, or a combination of both. Final delivery to all consumers is through a service and meter and frequently a transformer installation. This group is the third major component part of rural electric facilities.

The system may be conveniently divided into three segments: (1) the transmission and substation, (2) the distribution segment, and (3) the consumer's facilities. Each has an effect on quality and cost of electric service. Transmission and distribution facilities are closely related and necessarily interdependent.

The value of sound and economic design is ever so important. Should management reach a decision for an investment based upon unsound economic estimates, it could suffer extensive financial losses, a great part of which could never be recovered. The engineering literature is a source of many principles of sound economic analysis

which oftentimes are ignored in favor of strong individualistic viewpoints, insufficient study (sometimes by "cut-price" engineering fees), or simple inexperience.

The purpose of this paper is to outline significant factors to be considered in exploratory designs of rural electric systems, desirable objectives and new methods of approach that warrant consideration.

CONSUMER REQUIREMENTS

Inasmuch as the consumer's meter is the final point of delivery, his demands will dictate the type of service rendered. There is considerable speculation on this element of the industry. One viewpoint is that multiphase service will be abundantly available as a natural development of the distribution system, and will be asked for by a high percentage of the consumers. The suggestion is that "by multiphasing more lines, the result is to have three-phase lines available to such an extent that discriminatory rates for three-phase service will no longer exist." 1*

Also, there is this viewpoint of a manufacturer's representative (taken out of context):

> "Studies made of three-phase, higher-secondary-voltage distribution system for residential service," said Mr. R. F. Lawrence, Westinghouse Electric Corporation, (before the American Power Conference), "indicate that it would be the most economical system and would have the greatest flexibility among possible systems for this type of service. Secondaries would be a nominal 265/460 voltage system with most houses served at single-phase, two-wire, but three-phase, four-wire could be provided if required." 2*

The authors, however, have found little to either substantiate or refute these premises, but are more inclined to accept the viewpoint that three-phase service will continue to be the exception (and treated as such) for the average farm and urban consumer.

BASIC CONSIDERATIONS OF EXPLORATORY DESIGNS

Continuity of Service

Engineering and management realize dependable service is probably the most important factor in maintaining satisfactory consumer relations and one of the best inducements to increased use of electricity. In all long-range planning there should be a constant endeavor for improvement.

One viewpoint is to work toward a distribution voltage network or loop-type of design, making connections and/or interconnections available at various points in the system. Generally, this is accomplished with a radial type of transmission or subtransmission. Figure 1 is illustrative in a measure of this approach.

During the past few years, benefits of connecting multiphase feeders between substations on 7.2/12.5 kv systems have been widely discussed with apparently little attention to their limitations under peak conditions and the rapid rate their capability is reduced under normal load growth even with adequate sources of power and substation capacity available.

*Denotes references listed at end of paper.

Where substations are supplied from different sources, decisions as to probable savings in consumer hours lost, if any, by transferring the load to other substations, may, under certain conditions, pose a difficult problem to operating personnel. Oftentimes they are not cognizant of the capabilities and limitations of the power flow.

Until such time as improvements in the art of relaying make automatic transfer of distribution loads possible at costs commensurate with savings over manual operations, other methods must be considered.

The other viewpoint, and the one that the authors believe to be preferable, is to emphasize reliability through a loop, or grid, type of transmission (or subtransmission) that feeds a radial type distribution circuit. Figure 2 illustrates a condition where this type of approach in design might have been realized to advantage. Figure 3 schematically illustrates what appears to be a natural pitfall in the type of development mentioned above, while Figure 4 schematically illustrates the latter.

Regardless of ownership, advantage may be taken of transmission loop with three-way manual switching at each substation. Two or more sources offer the opportunity for remote control switching at each supply point. While this plan lacks the advantage of making load shifting between sources of supply possible, no problems in regulator switching or sectionalizing arise and its simplicity is a distinct asset to system operation.

Comparative investments on additional transmission against additional distribution facilities and reserve substation capacity vary widely with supply voltages, and each situation must be studied on its own merits. A combination of the two methods may prove desirable in some instances, particularly when the distribution voltage is 14.4/24.9 kv.

<u>Flexibility of Expansion</u>

Engineering and management also realize load growth is seldom uniform throughout all sections of a given area and marked local increases are possible with changes in farming methods, adoption of irrigation, etc. The necessity of yearly reviews to determine adequacy of plans previously proposed cannot be over-emphasized.

Maximum use of existing facilities should be uppermost in the mind of the distribution engineer to minimize obsolescence and to avoid excessive inroads on depreciation reserves. Expansion of the system capability should be such that the existing plant is utilized to the fullest extent consistent with quality of service and economy.

<u>Economy in Design</u>

Equally consistent with the value of flexibility and continuity of service is the value of economy in design. It should be objective of the design engineer to provide an ever-increasing efficiency in plant. There are several criteria for this, but it is suggested that these three simple tests be given:

1. The ratio of the total plant investment to the total KWH delivered per year.

2. The total unit cost per KWH delivered to the consumer including the cost of power or generation, transmission, transformation of voltage, distribution, and service requirements.

3. The investment and annual cost per KW of consumer service capacity.

The general overhead costs on the investment is one of the prime factors in selection of any basic design or plan of expansion of capabilities of electric systems. Too frequently engineering and management are confronted with the problem of comparing relative merits of two or more plans on the basis of yearly costs that involve figures of six to ten digits. The processing is materially simplified when reviewed on the basis of investment per KWH delivered. Yearly trends in investment per KWH at various KWH consumption levels may also be used in evaluating merits of each plan. Figure 5 shows the past trend on this basis and the current objective. Example 1 in the Appendix illustrates a method of comparing the relative annual costs of component parts of a system.

Wholesale power costs at the substation are affected by transmission investment, regardless of ownership. Costs of power at the consumer's meter are affected by distribution investment which, in turn, is governed to some extent by the number of substations or points of delivery made possible by investment in transmission plant.

A well chosen balance between the component parts of the system is, of course, the desirable objective. The authors present that the selection should be preferably made on the basis of annual costs as related to power delivery capability as nearly as possible. Again, referring to Example 1, and remembering that the design engineer is in reality only providing electrical capacity for the consumer's needs at the meter (even though back of it may be a complexity of distribution, transformation, transmission and generation), it is here that the economy should rule. The combination of design facilities should be selected that will yield the lowest annual cost per KW at the meter.

Also, it appears advisable to explore the probable financial trends with respect to future economy. As pointed out so succinctly by Mr. F. L. Lawton, in his paper, "Investment Costs for Use in the Economic Comparison of Alternate Facilities," 3* the relative value of money may change. To quote from his paper:

> "The paper concludes with the brief observation on the fact that the economic comparison of alternate facilities in the conventional manner, in view of the long-term decline in the value of the dollar, may not be too sound since the facility with the longest life, even though entailing greater investment, may well be the cheapest in the long run."

<u>Sectionalizing</u>

As consumptions increase, it is reasonable to anticipate that there will be a correspondingly greater demand for service continuity on the part of the consumer.

Reduction in substation area boundaries as one means of improvement and increases in capacity of transmission systems will tend to minimize many current sectionalizing problems. Potentials for improvement in the art must also be recognized.

The authors are of the opinion in exploratory system design that quality, flexibility and economy of service should be considered the primary objective and the apparent sectionalizing problems of today of secondary importance in designs for 10 to 25 years in the future.

*Denotes references listed at end of paper.

METHODS OF APPROACH TO EXPLORATORY DESIGNS

Perhaps the best approach is to use the "Iranian Desert Approach to System Planning" 4* spotting loads and load centers on a blank area map, designing a theoretical system, superimposing it over the existing system, and then adjudicating differences. Unlike the early post War II conditions, the rural distribution engineer of today is faced with the problem of design for a practically fixed number of consumers, barring, of course, marked changes in farming methods such as irrigation which could materially alter individual requirements and consumer density. In other words, the problem can be viewed from the standpoint of delivery of electric power to a group, or groups, of consumer loads under conditions similar to residential areas in urban districts, applying coincidence factors to load and annual costs to investments.

One factor is the selection of substation size. Figure 6 shows the approximate area per substation for different KWH loads in an area of four consumers per square mile. (Similar family of curves can be used for other densities.) Note that at 1200 KWH/month a 1000 KVA sub is limited to approximately 100 square miles. From these curves it would influence one to select larger substations as the consumption increases in order to avoid an excessive number of stations. Furthermore, the investment per KVA decreases decidedly with size as shown in Figure 7. This is still further argument for larger substations and a consequent reduction in the transmission mileage. These factors must be carefully weighed against the increased costs of distribution feeders. Here, consumer density plays an important role.

With rural density varying from a low of 0.25 to a high of 15 consumers per square mile the planning of transmission, substation, and distribution facilities necessary at 2 to 6 times current consumer consumption level represents individual problems for each system. Universal guide lines for country-wide use must be flexible enough that alterations to meet local conditions are possible and should be offered with extreme caution.

A few simple basic facts should be considered in planning improvements for rural distribution systems at 2 to 6 times consumptions for which the system was originally designed. These are:

1. Increasing the length of a feeder and length of area supplied by that feeder increases drop in voltage as the square of the length.

2. Increasing the width of the area served by a feeder increases demand and drop in voltage in direct proportion.

3. Increasing both width and length of area served by a feeder affects the drop in voltage as the square of the length and directly as the width.

Above statements may appear broad and following illustration is offered as proof of what takes place with changes in substation area boundary lines. Investment in new transmission facilities and/or substations will undoubtedly be required by most of the 1000 REA borrowers' distribution systems when consumptions approach 1000 KWH/month levels.

*Denotes references listed at end of paper.

The basic formula for Voltage Drop is:

> Volts Drop = demand in KW times Distance times a constant designated as Wire Factor that represents a combination of the characteristics of a given line such as voltage, phasing, conductors, and power factor of the load.

Demands are either obtained by actual measurements or estimates are determined by application of load factors to maximum average consumptions that are anticipated and coincidence factors to number of consumers supplied by a given section of line.

This Voltage Drop = (Consumers x Consumption x Constant) x Distance x Wire Factor (a Constant).

By disregarding the constant affecting demand and assuming there is no change in line characteristics the equation becomes:

> Voltage Drop = Consumers x Consumption x Distance

With voltage drop affected only by consumers and distance, at given consumptions, review of factors affecting capability of substation feeders is materially simplified.

Refer to Figure 8.

Area within the boundary lines between S_2, S_{11}, S_{12}, and S_{13} represents a typical rural area, in this case 12 miles square, except for the fact the substation is located in the exact center of the project, and for purpose of this discussion it will be assumed there is an equal distribution of consumers throughout the project and there are no natural barriers or inroads of foreign utilities that affect construction.

> Note: It might also be stated typical areas are not infrequent in the Middle-west where variations in consumers per mile result in less than 5% error in voltage drop figured on a basis of the average.

The area has been divided into 4 equal sections — A_1, A_2, A_3 and A_4 — and each is supplied by a substation feeder.

All consumers are fed from laterals off the main feeder lines. Each lateral serves an equal number of consumers that are evenly distributed along its entire length. Primary taps to consumers are disregarded.

Let C_A = Total consumers in Section A

C_B = Total consumers in Section B
and so on down through

C_I = Total consumers in Section I

also $C_A = C_B = C_C$ and likewise down through C_I.

Voltage drop at last consumer C_L will consist of the combined drops in sections of substation feeder. Substation to L_1, L_1 to L_2, L_2 to L_3, and in lateral L_3 to last Consumer C_L.

SECTION

Sub. to L_1 ;	Volts Drop	= 1 mi. x C_A	= 1 C_A miles
L_1 to L_2 ;	" "	= 2 mi. x 2/3 C_A	= 4/3 C_A miles
L_2 to L_3 ;	" "	= 2 mi. x 1/3 C_A	= 2/3 C_A miles
Total in substation feeder			3 C_A
L_3 to C_L	Volts Drop	= 6 mi. x 1/2 (1/3 C_A)	= 1 C_A miles
Substation to Last Consumer C_L			4 C_A miles

If we increase the area served to 24 miles each way and maintain symmetry about the substation, section of area within the boundary lines Substation, S_4, S_5, and S_6 will be supplied by this feeder.

Voltage drop at last Consumer C_{L1} will consist of combined drops in sections of the Substation Feeder -- Substation to L_1, L_1 to L_2, L_2 to L_3, L_3 to L_4, L_4 to L_5, L_5 to L_6, and lateral L_6 to last consumer C_{L1}.

SECTION

Sub. to L_1 ;	Volts Drop	= 1 mi. x $C_A + C_D + C_B + C_C$	= 4 C_A miles
L_1 to L_2 ;	" "	= 2 mi. x 2/3 $(C_A + C_D) + C_B + C_C$	= 6 2/3 C_A miles
L_2 to L_3 ;	" "	= 2 mi. x 1/3 $(C_A + C_D) + C_B + C_C$	= 5 1/3 C_A miles
L_3 to L_4 ;	" "	= 2 mi. x $(C_B + C_C)$	= 4 C_A miles
L_4 to L_5 ;	" "	= 2 mi. x 2/3 $(C_B + C_C)$	= 2 2/3 C_A miles
L_5 to L_6 ;	" "	= 2 mi. x 1/3 $(C_B + C_C)$	= 1 1/3 C_A miles
Total in substation feeder			24 C_A miles
L_6 to C_{L1} ;	Volts Drop	= 12 mi. x 1/2 $\left[1/3\ (C_B + C_C)\right]$	= 4 C_A miles
Volts Drop; Substation to last consumer C_{L1}			28 C_A miles

Identical procedures were used in arriving at the drop to the last consumer when the area was expanded to 32 miles square, which consisted of:

Volts Drop in Substation Feeder equals . . . . . 56 8/9 C_A miles

Volts Drop in 16 mi. Lateral to last consumer . . 7 1/9 " "

Total to last Consumer C_{L2} . . . . 64 C_A miles

With area expanded to 36 miles square:

Volts Drop in Substation Feeder equals . . . . 81 C_A miles

Volts Drop in 18 mi. Lateral to last consumer C_{L3} . . 9 " "

Total to last Consumer C_{L3} equals. . . . . 90 C_A miles

When changes are made in equal amounts in all four directions, the total drop in voltage along the substation feeder increases as the square of the rate of change in length times the rate of change in width.

Example in expanding from area 24 mi. square to 36 mi. square, or 1.5 times:

Voltage Drop $= (1.5)^2 \times 1.5 \times 24\ C_A$ miles

$= 3.375 \times 24 =$ 81 C_A miles

Voltage drop in lateral L_6 to last consumer C_{L1} = 9 C_A miles

Total to last consumer C_{L1} = 90 C_A miles

While the foregoing illustration may appear unnecessary in proving a simple point, it does set out effects of changes in boundaries on various components of a substation feeder system.

As an example, increasing length of Lateral L_3 from 6 mi. to 12 mi., or twice, increases drop in voltage from 1 C_A miles to 4 C_A miles, or four times. Capability must be increased accordingly either by rephasing, if present line is single-phase, or reconductoring, or a combination of both.

Should we elect to supply in an emergency two areas J_A and K_A in adjoining project each being equal in size and consumers to A_1, the drop in voltage to last consumer will be affected in the following manner:

Assuming areas $J_A + K_A$ that are to be added to the present area Substation, S_7, S_8, S_9 are equal in size and have the same number of consumers as area A_1.

Voltage drop from Substation to Lateral L_9 will be increased as follows:

Section

Sub to L_9	Volts Drop	=	17 mi. x $(C_{KA} + C_{JA})$	=	34 C_A miles
L_9 to L_{10}	Volts Drop	=	2 mi. x $(C_{KA} + C_{JA})$	=	4 C_A miles
$L_{10} + L_{11}$	Volts Drop	=	2 mi. x 2/3 $(C_{KA} + C_{JA})$	=	2 2/3 C_A miles
$L_{11} + L_{12}$	Volts Drop	=	2 mi. x 1/3 $(C_{KA} + C_{JA})$	=	1 1/3 C_A miles

Total drop in the substation feeder to L_{12} = 42 C_A miles
Or an increase of approximately 52%.

Drop in the lateral L_{12} to last consumer C_{L4} = 4 C_A miles

Total to C_{L4} . . . . 46 C_A miles

An overall increase to last C_{L4} of 51%

Drop to last consumer C_{L3} would be increased by the increase in section (Sub to L_9) of 34 C_A miles, or approximately 38%.

Thus, in supplying concentrated loads of adjoining areas by means of distribution loop feeders, voltage conditions are affected back to the source and either capability of laterals as well as substation feeders increased over normal requirements or regulators installed, or a combination of both.

The authors have attempted to call attention to some of the many aspects of future electrical distribution planning. While not always stated, a 7.2/12.5 kv distribution voltage was implied.

Realizing the broad scope of the title, each was described as briefly as possible. With only a very limited amount of factual information to draw from in many instances, hypothetical illustrations were mandatory except for some of the data in appendix and figures.

CONCLUSION

The future exploratory system should be based upon a weighted analysis of the annual costs of all the component parts of the system involved up through the consumer's meter. It is suggested that lesser reliability should be placed on distribution voltage network and greater reliability placed on the higher voltage circuits. Distribution feeder voltage drop increases as the square of the rate of change in length times the rate of change in width when the area is equally increased in all four directions.

System expansion improvements will come high and will justify engineering of the highest caliber. There appears to be no simple formula or panacea, and when all the avenues of science have been carefully analyzed, the art of experienced judgment should prevail.

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E. H. Breckenfelder, Stanley Engineering Company, Muscatine, Iowa

E. R. Mackie and Y. Huntsader, Ellerbe & Company, St. Paul, Minnesota

C. P. Wagner, Farm Electric Consultant, North Central Electric League, Minneapolis, Minnesota

Roland W. Schlie, John F. Atkinson, Gordon R. Messmer, and others, Rural Electrification Administration, Washington, D. C.

REFERENCES

1. The Availability of Three-Phase Distribution for Farm Consumers, Everett Dill & James Kiley. AIEE Conference on Farm Electrification, C.P. 56-1061.

2. Industry in Conference, Highlights of American Power Conference. Electric Light & Power, April 15, 1956; p. 124.

3. Investment costs for use in the Economic Comparison of Alternate Facilities, F. L. Lawton. AIEE Technical Paper 52-61.

4. Iranian Desert Approach to System Planning, John Werner. Electric Light & Power, June 15, 1956.

TABLE I

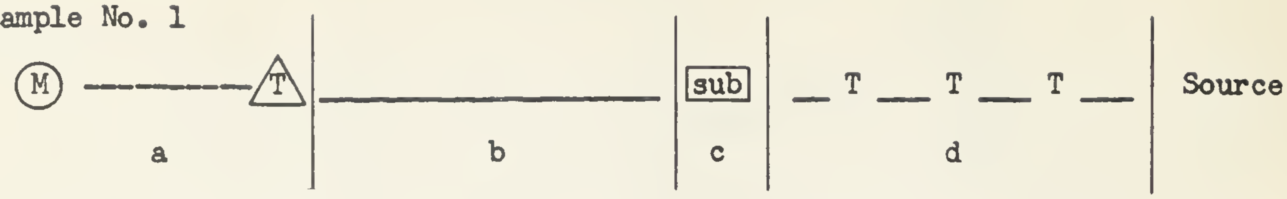
CONSUMER DEMAND BASED ON AVERAGE DENSITY OF 1 to 3 PER SQUARE MILE

DEMAND AT LOAD EQUALLY DIVIDED BETWEEN 4 SUBSTATION FEEDERS

	Demand at 300 KWH/Month			Demand at 600 KWH/Month			Demand at 1200 KWH/Month			Demand at 2400 KWH/Month			Average Demand Per Consumer		
Area and Consumers	1 per sq. mi.	2 per sq. mi.	3 per sq. mi.	1 per sq. mi.	2 per sq. mi.	3 per sq. mi.	1 per sq. mi.	2 per sq. mi.	3 per sq. mi.	1 per sq. mi.	2 per sq. mi.	3 per sq. mi.	1 per sq. mi.	2 per sq. mi.	3 per sq. mi.
6 mi. sq.-36 sq. mi. 9 sq. mi./Feeder	13.7	24.6	34.3	25.1	45.2	63.2	46.6	83.8	117	73.3 88	132 159	184 221	9.8kw	8.9kw	8.2kw
12 mi. sq. 36 sq. mi./Feeder	44	80.9	116	81.1	149	213	150	276	390	236 283	434 522	622 747	7.9	7.3	6.9
24 mi. sq. 144 sq. mi./Feeder	149	281	410	275	517	754	511	953	1398	803 965	1505 1810	2198 2630	6.6	6.3	6.1
32 mi. sq. 256 sq. mi./Feeder	252	484	721	463	873	1326	859	1650	2458	1350 1620	2594 3110	3861 4640	6.3	6.1	6.0
36 mi. sq. 324 sq. mi./Feeder	313	610	909	676	1119	1668	1067	2078	3098	1660 2001	3267 3920	4871 5850	6.2	6.0	6.0

APPENDIX

Example No. 1



One-line Diagram of a System

Formula: $$Q = \frac{Ia\ (x)}{(N)\ KW_a} + \frac{Ib\ (x)}{\frac{(N)\ 2KW_a}{1+D_b}} + \frac{Ic\ (x)}{\frac{(N)\ KW_a}{D_c}} + \frac{Id\ (x)}{\frac{(N)\ KW_a}{D_d}} \qquad (1)$$

Where	Q	=	Annual costs per KW at meter
	I_a	=	Plant investment in segment a
	I_b	=	" " " " b
	I_c	=	" " " " c
	I_d	=	" " " " d
	X	=	Annual costs of investment expressed in fraction
	N	=	Number consumers in system
	KW_a	=	System capacity at meter
	D	=	Diversity factor

Data and constants used:

I_a	-	\$741,000	N - 4000
I_b	-	\$1,103,000	KW_a - 6 (600 kwh)
I_c	-	\$140,000	(7 substations of 2 ckts each)
I_d	-	\$58,000	D_b (max) = 3.25 (571 consumers)
X	-	0.1 (or 10%)	$D_c = D_d$ = 3.1 (285 consumers)

Substituting in eg (1) and solving

$$Q = \$3.08 + 9.41 + 1.90 + 0.73$$
$$= \$15.12 \text{ per KW per year}$$

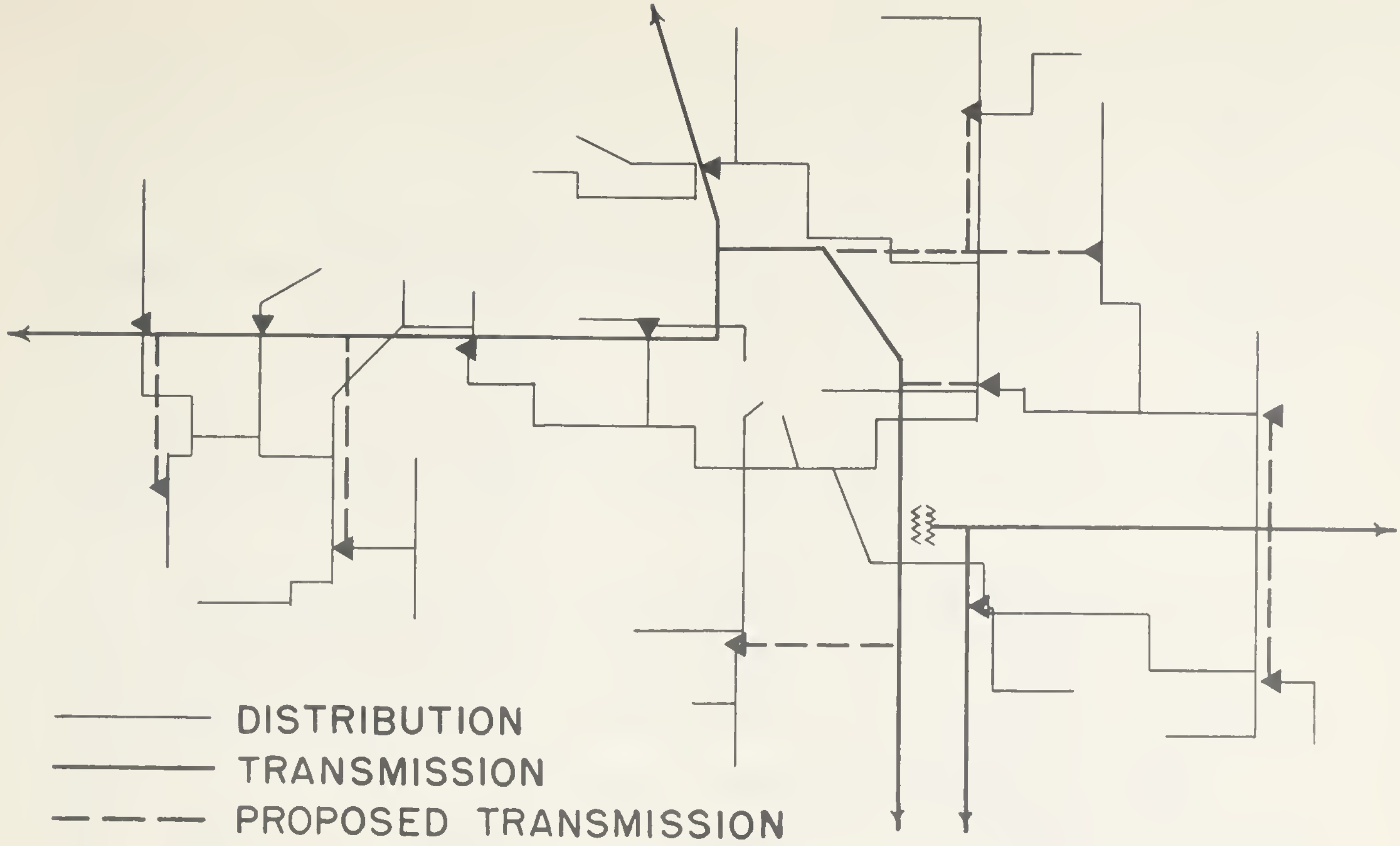


Fig. 1. A future distribution plan
@ 2,000 KWH/consumer/month

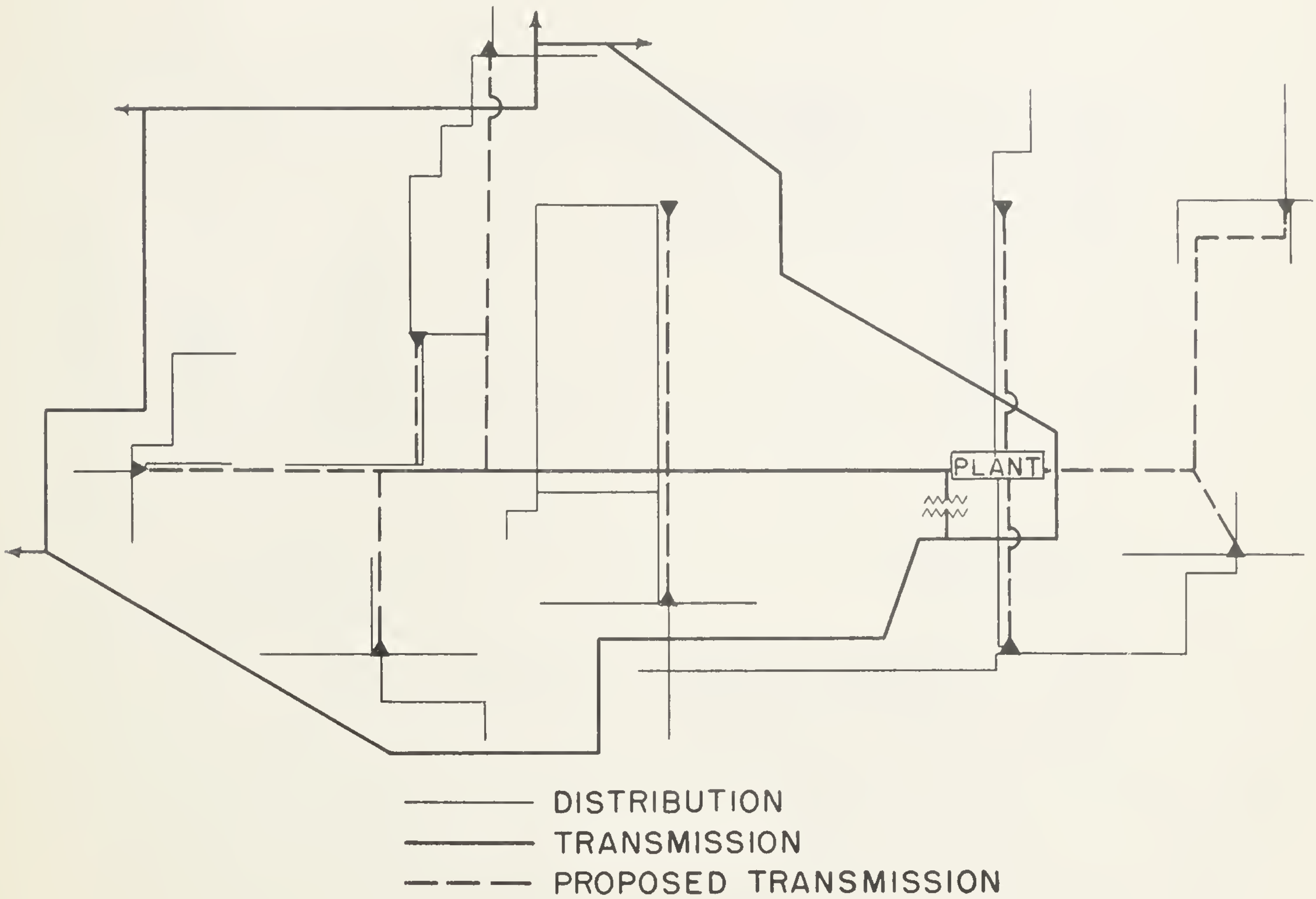


Fig. 2. Another future distribution plan
@ 2,000 KWH/consumer/month

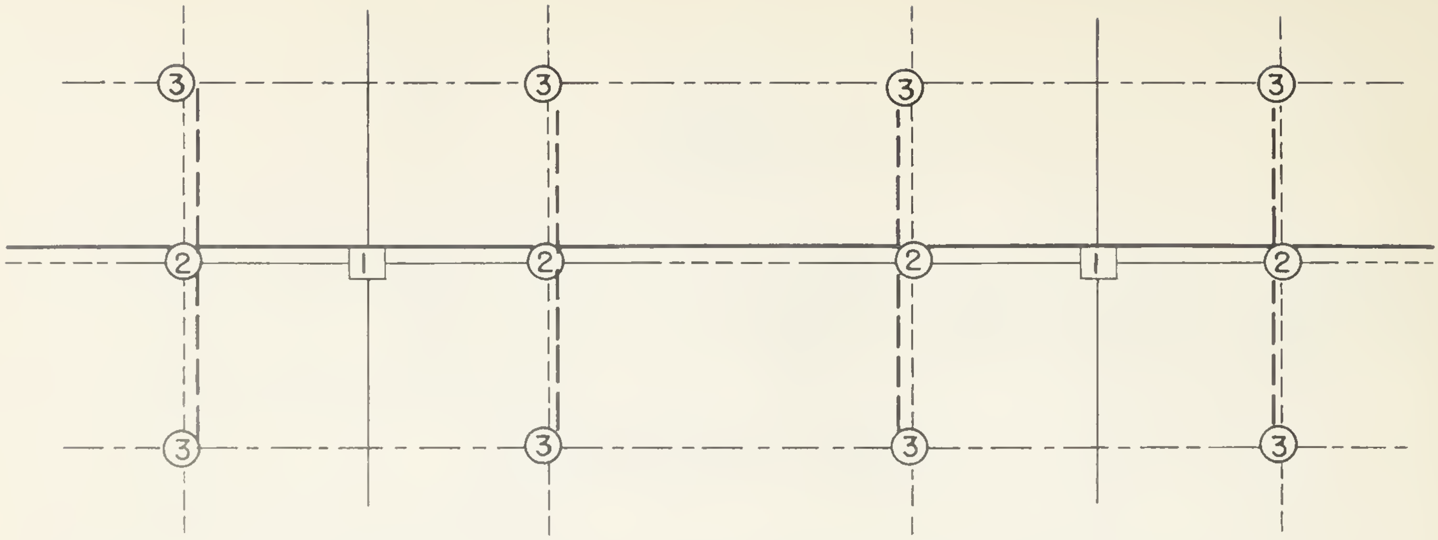


Fig. 3. Undesirable design: grid distribution, radial transmission

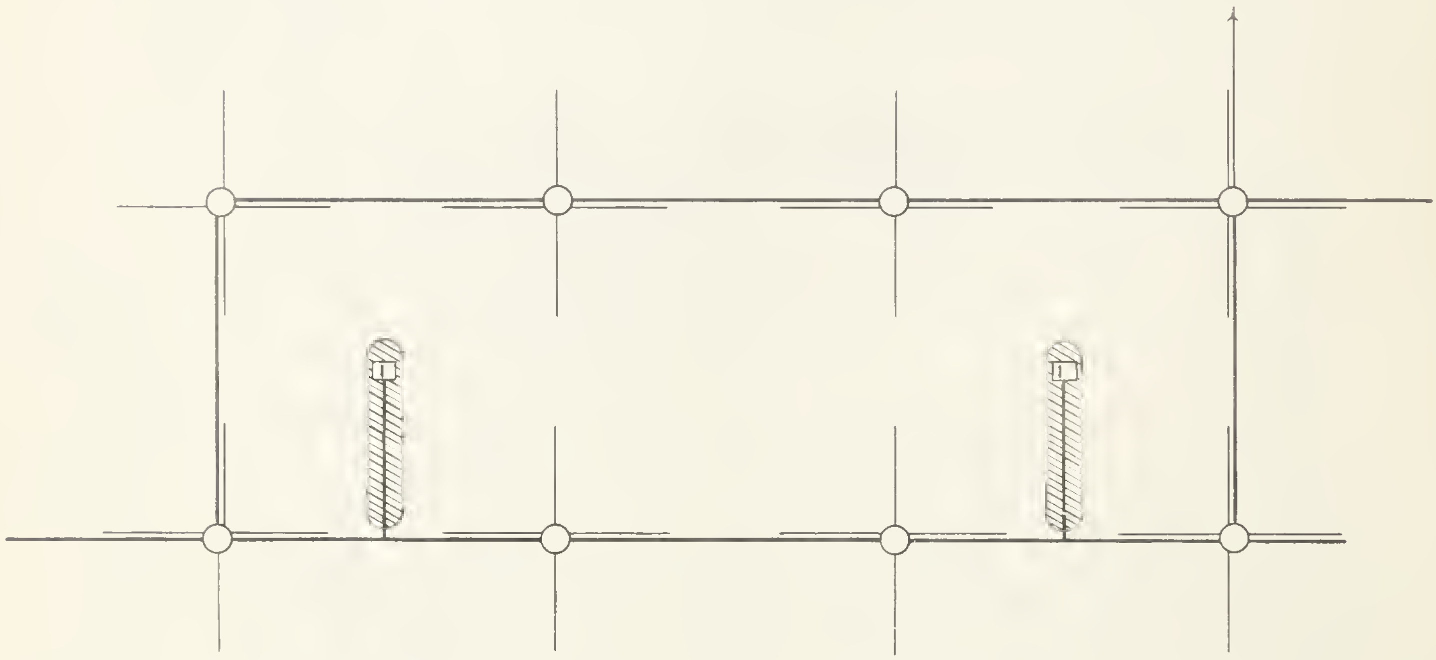


Fig. 4. Preferable design: grid transmission, radial distribution

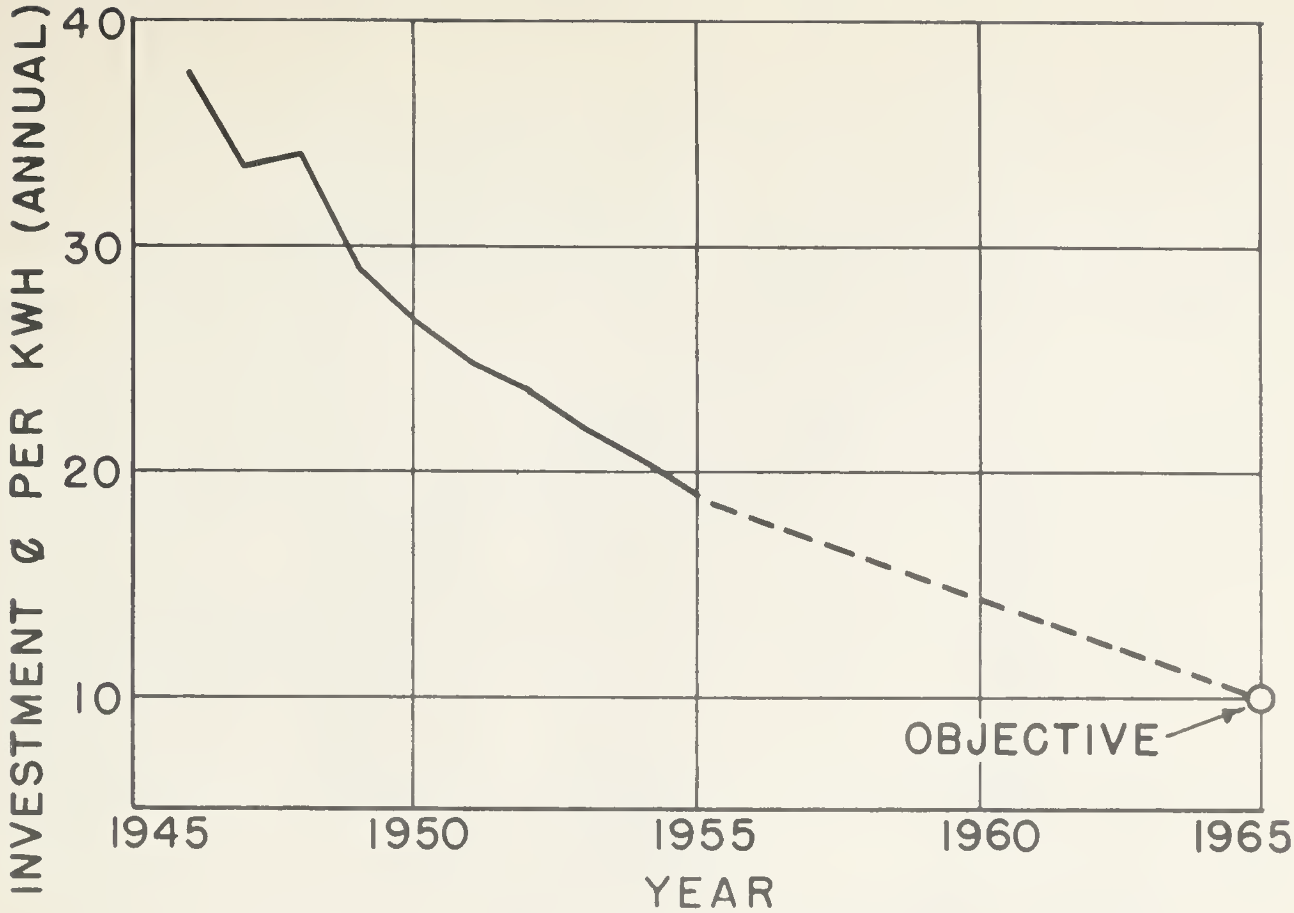


Fig. 5. Desirable trend in reduction of ratio of plant investment to KWH sales

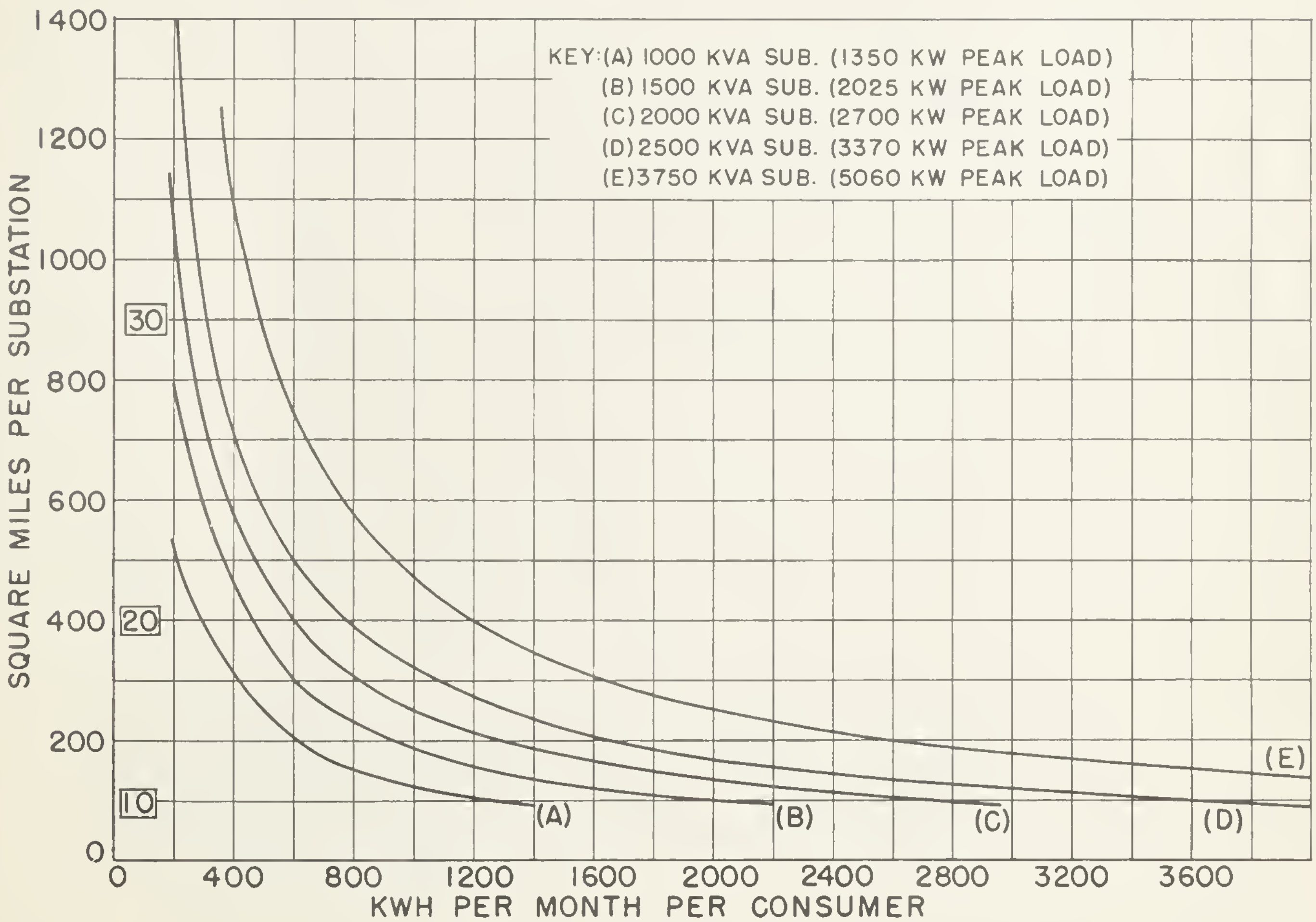


Fig. 6. Relationship of substation area to consumer use. Four consumers per square mile.

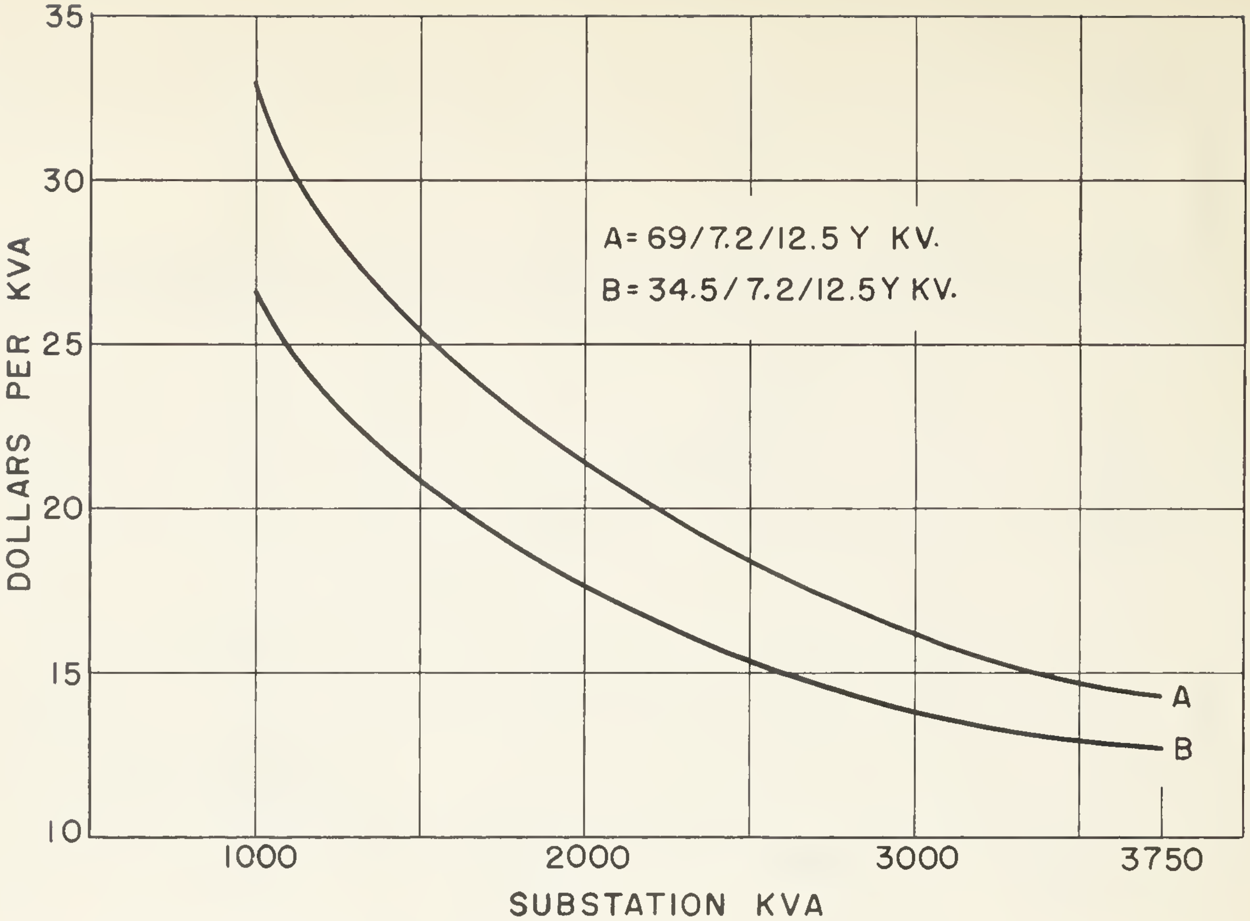


Fig. 7. Approximate substation cost per KVA

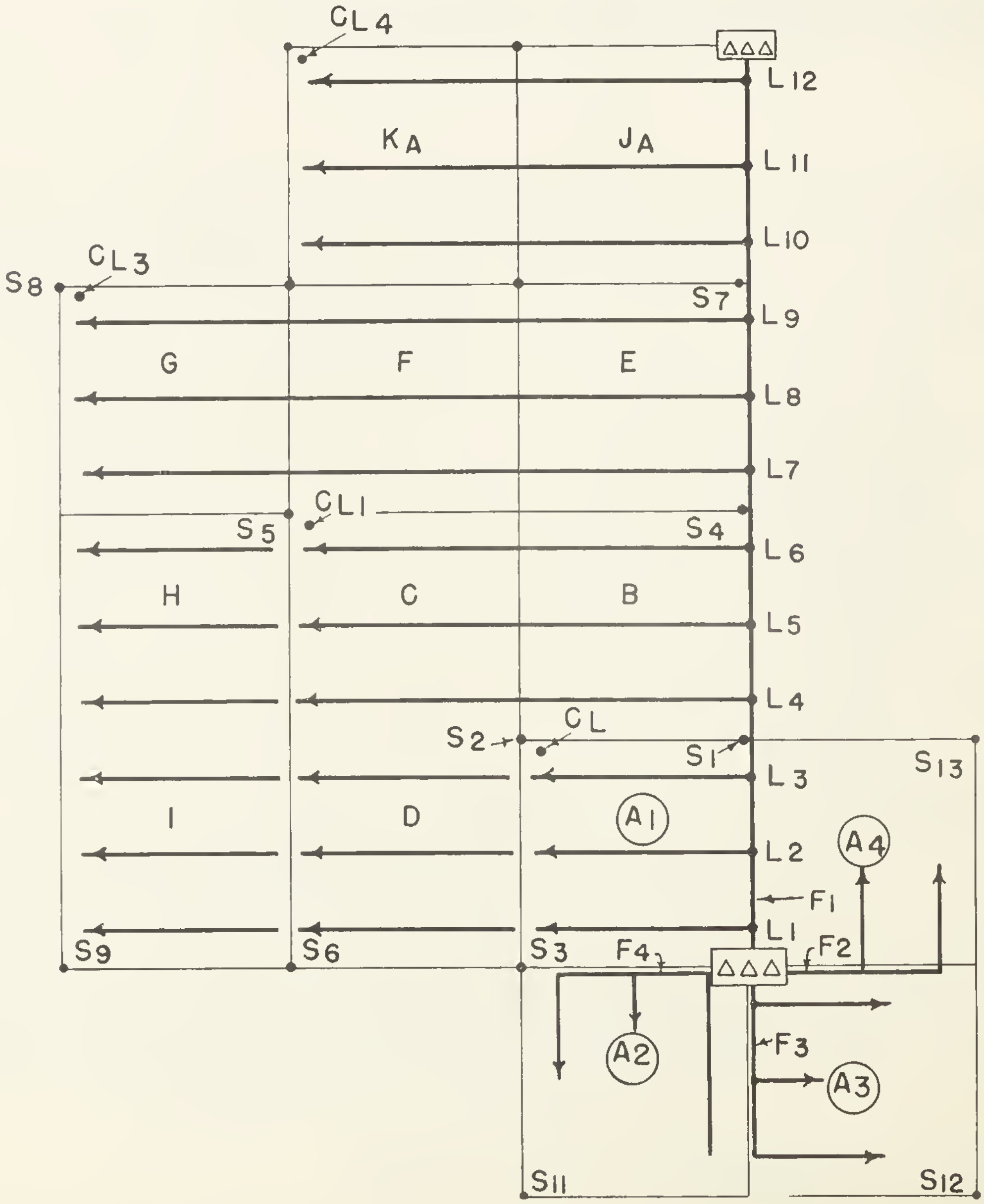


Fig. 8. Distribution area development

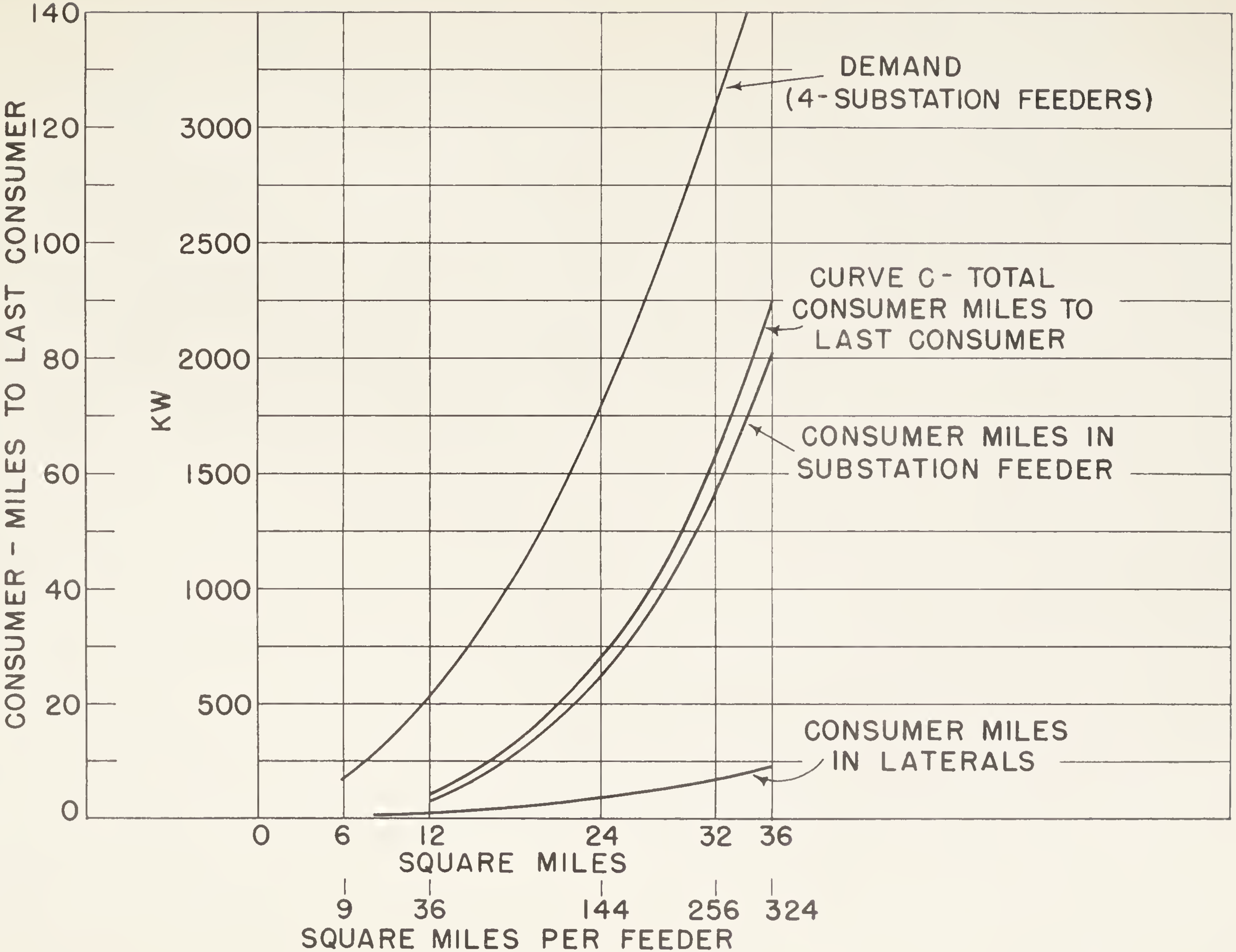


Fig. 9. Demand per sq. mi.; density of 2;
2400 KWH/month/consumer

RECENT CHANGES IN LINE DESIGN

By James M. McCutchen
Radio-Electrical Coordination Engineer
Electric Engineering Division

For Presentation at the 1957 Technical
Conference for REA Field Engineers,
New Orleans, Louisiana, January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural
Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experiences which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

RECENT CHANGES IN LINE DESIGN

James M. McCutchen

The title of this paper might more properly be: "What Have You Done To The Spec. Books Now?" and "How Come?". In order to answer the two basic questions posed, a bit of background might be helpful.

From the date of issuance, REA Form 804 (Specifications and Drawings for 7.2/12.5 KV Construction) (June 1953) has been subject to criticism from the field. Reasons given: 1. There are too many drawings in the book. 2. There are not enough drawings in the book to cover special situations. 3. The drawings which are in the book need revisions to incorporate improved designs.

In order to answer 1 and 2 above, and attempt to satisfy item 3, the work on revising REA Form 804 was broken down into three major steps: 1. To determine the extent of use of each drawing by reviewing inventories on borrowers' systems throughout the country. 2. To establish a listing of the most popular and the least used drawings and to arrange for incorporation of these drawings in two volumes. 3. To incorporate improvements in all drawings and at the same time, provide for conversion of assemblies with minimum field changes in the existing pole arrangement. Mr. W. L. Woehler has done a yeoman-like job in coordinating these efforts. At the same time that the drawings were selected for incorporation into the two categories, they were revised to include improvements in assembly arrangements as suggested by people in the field and by members of the Washington staff.

Basis for Revision in Ground Wire Arrangement

Let us review one of the field and staff investigations which has led to extensive revisions in the pole top assembly drawings. We might consider the work which has been done on the location of the pole protection ground wire from the standpoint of minimizing radio and television interference problems and providing more effective lightning protection. You know this pole ground wire thing sort of grew at random from the early days of REA to the present. The original drawing assemblies had no ground wire above the neutral up until about 1938. A ground wire extension from the neutral to the pole top pin bolt was added after the loss of some poles from lightning in eastern Iowa in the summer of 1938. After a rash of radio interference troubles from loose connections at the pole top pin, the wire was disconnected from the pin, relocated to the side of the pole and extended above the pole top to slightly above the insulator skirt. After the electrocution of the required number of birds and various other forms of flying, crawling and climbing wildlife and the necessary number of fuse blowings with attendant outages and inconvenience to consumers, the ground wire was cut back to a point two inches below the pole top. This was done for the benefit of the birds and is strictly for the birds, as we found some years later. As an interim measure to minimize some of the interference problems, pole top ground wire extensions were removed from all drawings at single-phase transformer installations, and on three-phase transformer locations where the transformer, with its arrestor was attached to the center phase. This was done in July of 1954 with the issuance of REA Bulletin 83-1, "Adequate Grounding on Distribution Lines".

Additional work on radio interference investigation and lightning damage to pole top assemblies, led in the spring of 1955, to a series of tests on full scale pole top

assemblies at the High Voltage Laboratory of the National Bureau of Standards. We wished to determine whether the ground wire assembly we had was of value in pole protection schemes and if not, what arrangement would serve the purpose without at the same time introducing additional problems of radio and television interference with the attendant higher maintenance costs.

High Voltage Tests

Samples of typical assemblies were constructed in the laboratory and were used to compare the resistance of various assembly arrangements to steep wavefront lightning surges approximating direct strokes to the pole top. The tests were duplicated on wet wood and on thoroughly seasoned wood, both creosoted. High speed motion pictures were made of the shots and we have assembled a representative group of these shots and their results for your inspection. (Present film with commentary).

These tests led to the changes in the ground wire protection scheme which are represented by drawings M2-1, M2-11, M2-2, M2-12 and M2-9. Instead of showing ground wire arrangements on each drawing as was done in the 6-53 issue of REA Form 804, a set of guide drawings M30-1 and M30-2 in the 8-56 issue show the ground wire arrangement on different types of assemblies.

REA Bulletin 45-6, "Tests of Pole Grounding Assemblies" describes the reasons for the changes in ground wire protection arrangement and shows the new locations for the ground wire as determined from the high voltage tests.

General Results of 7.2/12.5 KV Drawing Revisions

The present drawings are grouped in two general classes: REA Form 804 contains the most commonly used drawing, printed on standard weight paper, with revisions as determined from your suggestions and from laboratory investigations. Some new gimmicks have been developed since the last revision, such as cluster mounts for reclosers and transformers. REA Form 204 contains drawings used less frequently, printed on translucent paper for duplication in the field where required. All drawings incorporate minor modifications in guy and ground wire clearances with respect to ungrounded hardware. None of the drawings show the ground wire extensions dotted in as was the case with the previous issue. This former practice led to many errors in construction because the small scale of the drawings did not allow proper illustration of the correct location of the ground wire extension. (Slides illustrating typical drawings before and after with explanation of changes).

Revision of REA Form 803 14.4/24.9 KV Assemblies

As of this writing, revisions to the 14.4/24.9 kv drawings are not complete but the general procedure is the same. In this case, however, much work had already been done in revisions to pole assembly drawings because of the serious interference problems with earlier assemblies. This work has been continued in the current revision. In addition, more drawings have been added to REA Form 803 to cover more of the field requirements. For example, drawings have been developed for both crossarm and pole-bracket mounted single, "Vee" and three-phase transformer banks; drawings for various arrangements of oil circuit reclosers, etc. will be included. All drawings have been revised to incorporate sufficient clearances between phase hardware and grounds or guys on the pole to minimize radio and television interference problems.

Revision of REA Form 805 Transmission Drawings

The revisions to the transmission contract in the main were not as extensive as those in the other two classes of construction, consisting mainly of clarification of notes and dimensions on the drawings. For example, the designation of the size of crossarms was changed from a specified dimension as a "minimum" to a nominal dimension so as to agree with the tolerance table on the same drawing (TM-20).

An alternate designation was added to all TP drawings for the use of a 10 ft. crossarm, and TM-3 was changed to include a connection between the two pole grounds with both grounds tied in to the switch handle.

TM-9A was developed to provide a solid connection between the pole ground wire and the overhead ground wire support bracket instead of wrapping the ground wire around the support bracket bolt. On all anchor assemblies the height of the anchor rod eye above the ground was changed from 12 inches to 8 inches.

An index of construction drawings was added.

REFERENCES

1. REA Form 804, Description of Units, Specifications and Drawings for 7.2/12.5 KV Line Construction.

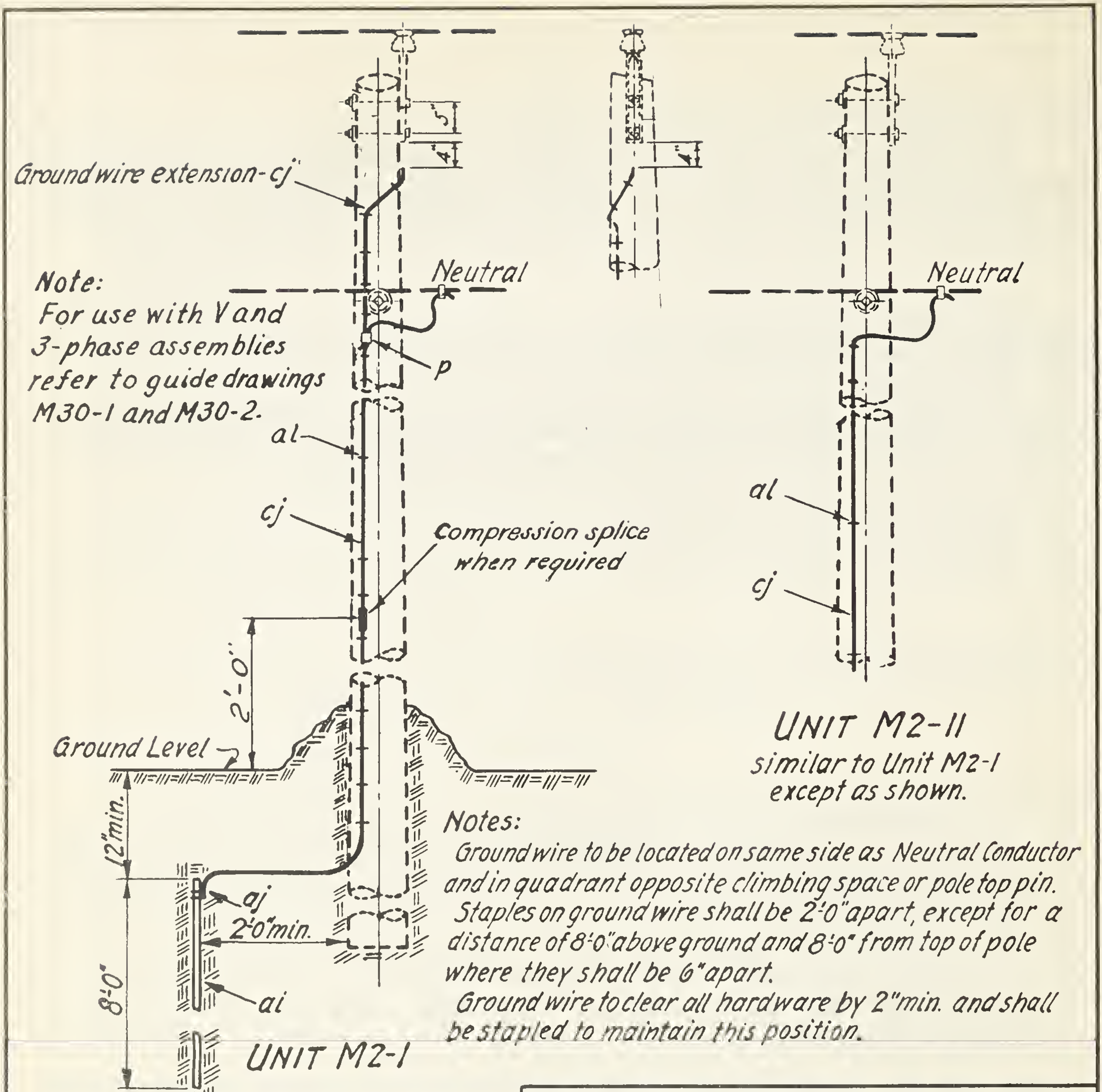
2. REA Form 204, Special Drawings for 7.2/12.5 KV Line Construction.

3. REA Form 803, Description of Units, Specifications and Drawings for 14.4/24.9 KV Line Construction.

4. REA Form 805, Description of Units, Specifications and Drawings for Transmission Voltages Line Construction.

5. REA Bulletin 45-6, "Tests of Pole Grounding Assemblies".

6. REA Bulletin 83-1, "Adequate Grounding on Distribution Lines".



Notes:
Groundwire to be located on same side as Neutral Conductor and in quadrant opposite climbing space or pole top pin.
Staples on ground wire shall be 2'-0" apart, except for a distance of 8'-0" above ground and 8'-0" from top of pole where they shall be 6" apart.
Ground wire to clear all hardware by 2" min. and shall be stapled to maintain this position.

ITEM	MATERIAL	ASSEMBLY UNIT M2-1	M2-11	
p	Connector	2	1	
ai	Rod, ground, 5/8" dia. min.	1	1	
aj	Clamp, ground rod	1	1	
al	Staples, ground wire, 3/16"x1½" #9, as req'd.			
cj	Ground wire. #6 S.D. Copper or equiv.	1	1	
cj	Ground wire extension, #6 S.D. Copper "	1		

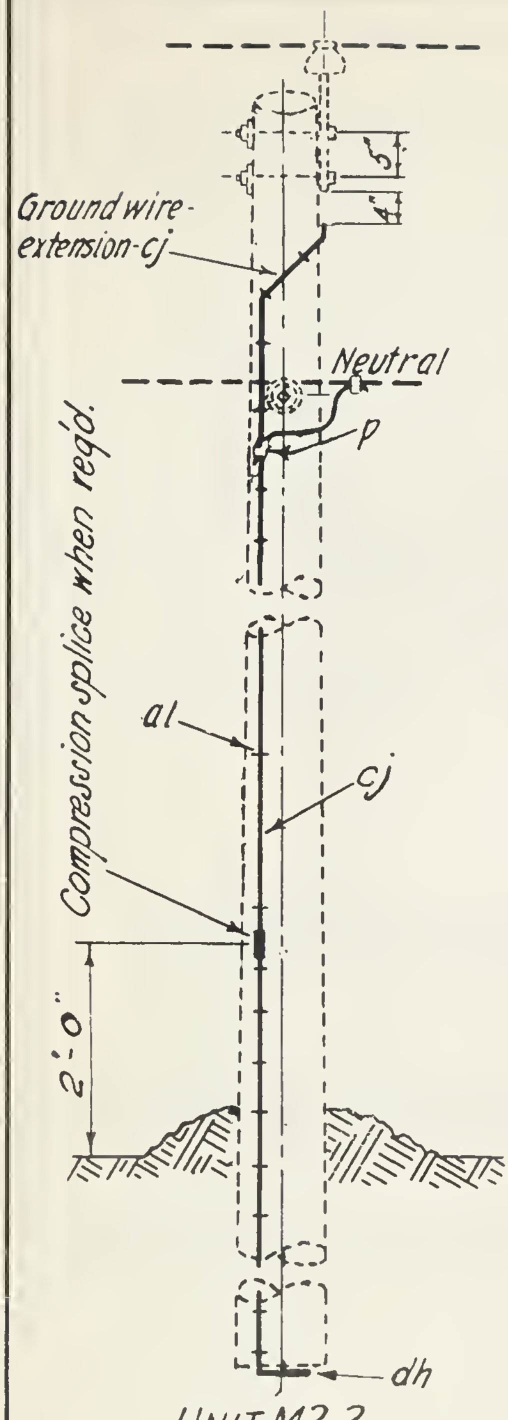
NO.	REVISION	DATE:
1	Revised	4-12-56

GROUNDING ASSEMBLY—GROUND ROD TYPE

Scale: ½"=1'-0"

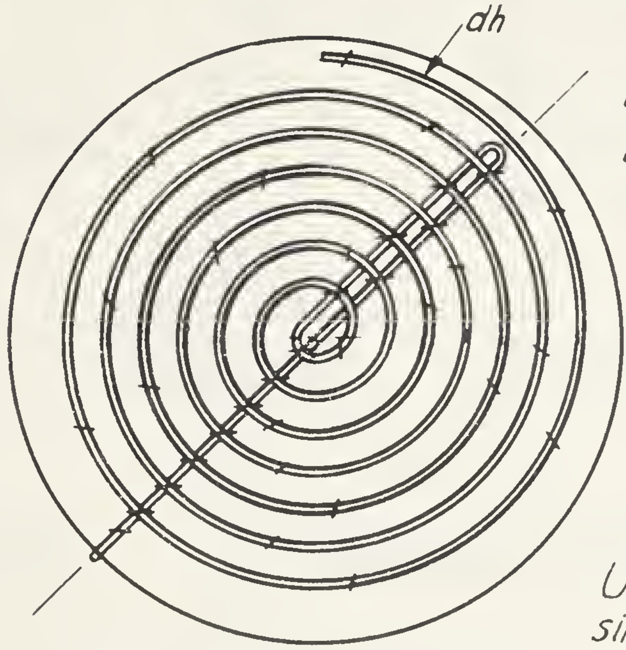
Date:

M2-1, M2-11.

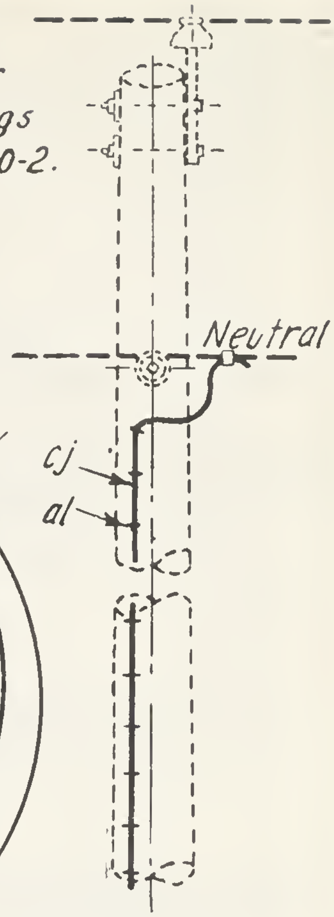


UNIT M2-2

Note: For use with V and 3-phase assemblies refer to guide drawings M30-1 and M30-2.



PLAN OF COIL TYPE GROUND
Scale: 3"=1'-0"



UNIT M2-12
similar to Unit M2-2 except as shown

NOTES:

Ground wire to be located on same side as neutral conductor and in quadrant opposite climbing space or pole top pin.
Staples on ground wire shall be 2'-0" apart, except for a distance of 8'-0" above ground and 8'-0" from top of pole where they shall be 6" apart.
Ground wire to clear all hardware by 2" min. and shall be stapled to maintain this position.

ITEM	MATERIAL	ASSEMBLY UNIT M2-2	M2-12	
p	Connectors	2	1	
al	Staples, ground wire, 3/16"×1½"×#9, as req'd.			
cj	Ground wire, #6 S.D. Copper or equiv'nt.	1	1	
dh	Butt type grounding device, coil or plate	1	1	
cj	Ground wire extension, #6 S.D. Copper	1		

POLE PROTECTION ASSEMBLY-BUTT TYPE
(COIL, PLATE OR ROD)

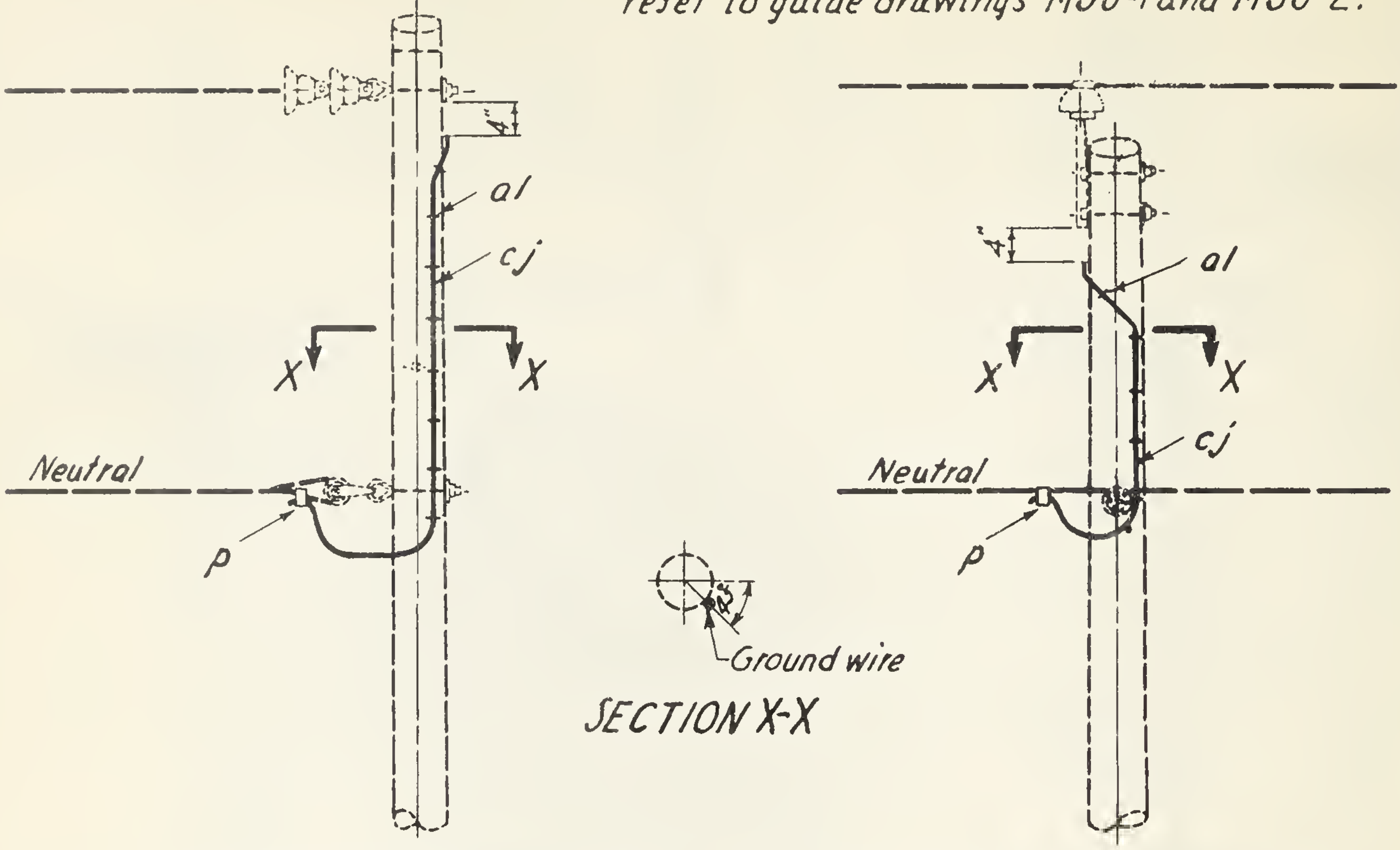
Scale: ½"=1'-0"

Date:

M2-2, M2-12

NO.	REVISION	DATE:
1	Revised	4-12-56

Note: For use with V and 3-phase assemblies refer to guide drawings M30-1 and M30-2.



DEADEND ARRANGEMENT

TANGENT ARRANGEMENT

NOTES:

1. Ground wire to be located on same side as Neutral Conductor and in quadrant opposite climbing space.
2. Staples on ground wire to be 6" apart.
3. Ground wire to clear all hardware by 2" min. and shall be stapled to maintain this position.

ITEM	NO. REQ'D	MATERIAL		ITEM	NO. REQ'D	MATERIAL	
p	1	Connector					
al		Staples groundwire, 3/16"x1½"					
cj		Ground Wire, #6 S.D. copper or equiv.					

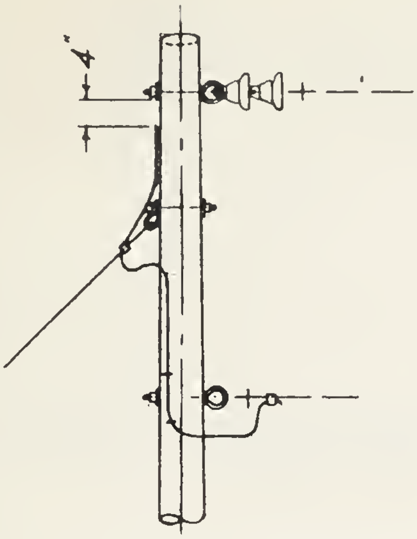
POLE TOP PROTECTION ASSEMBLY

NO.	REVISION	DATE
1	Revised	4-12-56

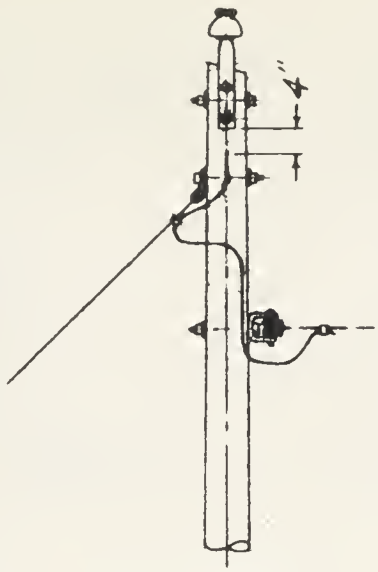
Scale: ½" = 1'-0"

Date: June 1, 1948

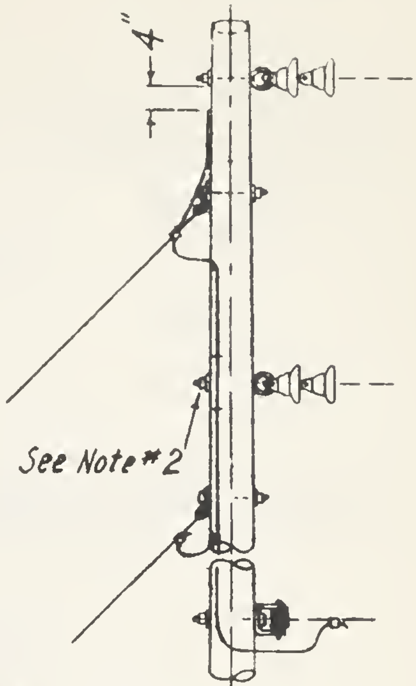
M2-9



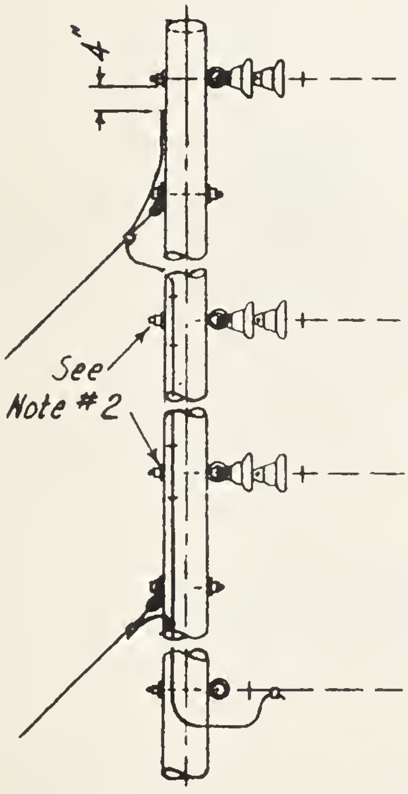
AT SINGLE PHASE ANGLES
AND DEADENDS



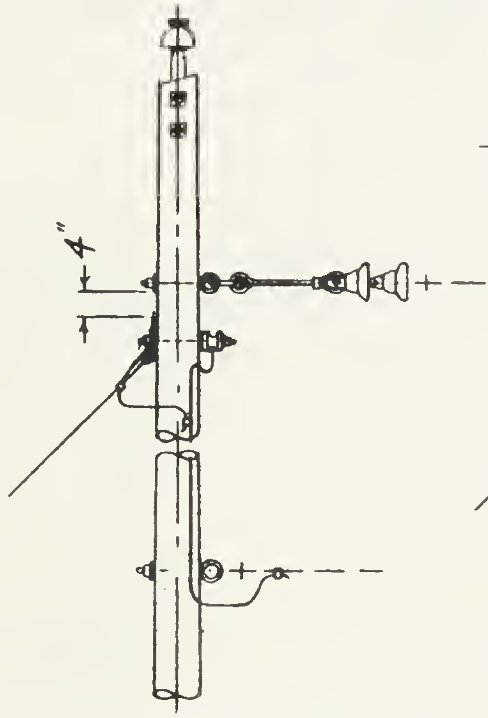
AT SINGLE
PHASE ANGLES



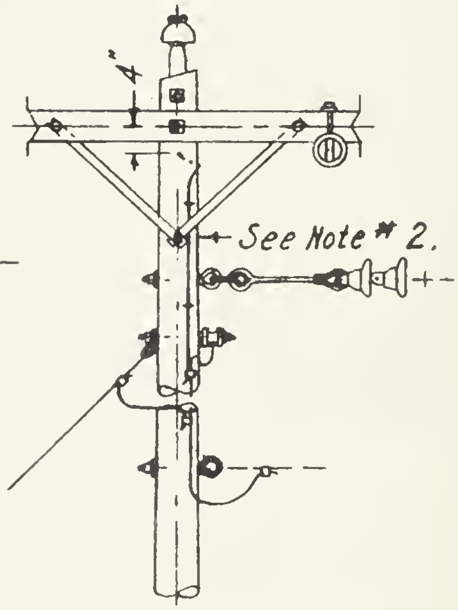
AT V-PHASE ANGLES
AND DEADENDS



AT THREE PHASE ANGLES
AND DEADENDS



AT SINGLE PHASE TAP ASSEMBLY

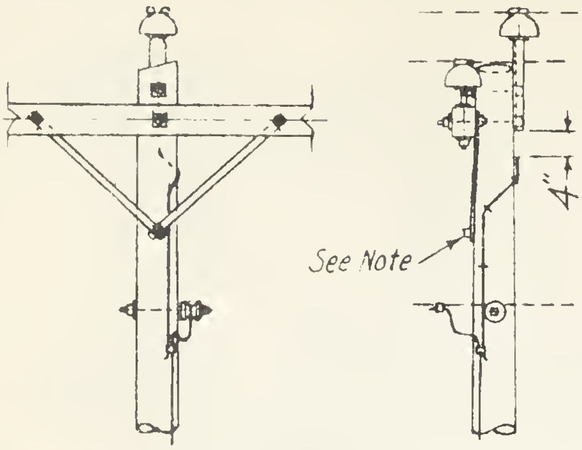


AT V OR THREE PHASE
TAP ASSEMBLY

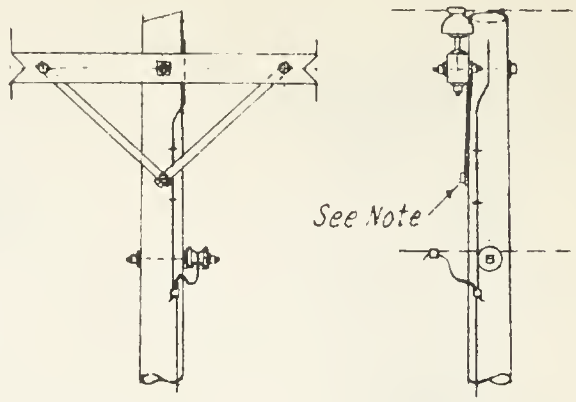
Notes: 1. An M2-12 ground assembly may be added if desired.
2. Position of staple is important. Maintain 4" min. distance from staple or clip to lag screw or eye bolt.

GUIDE FOR INSTALLATION OF GROUND WIRE
ABOVE NEUTRAL ON GUYED POLES

Scale: 3/8" = 1'-0"		Date: April 12, 1956
		M30-1

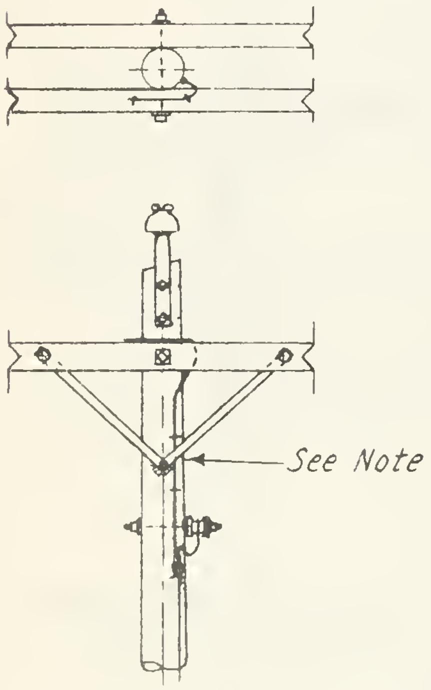


AT SINGLE ARM ASSEMBLIES WITH
POLE TOP PIN

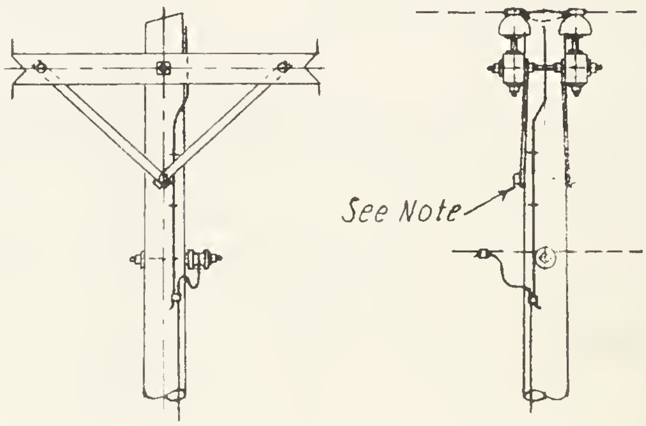


AT SINGLE ARM ASSEMBLIES WITHOUT
POLE TOP PIN

Note:
Position of staple is important.
Maintain 4" min. distance from
staple or clip to lag screw or eye bolt.



AT DOUBLE ARM ASSEMBLIES
WITH POLE TOP PINS



AT DOUBLE ARM ASSEMBLIES
WITHOUT POLE TOP PINS

GUIDE FOR INSTALLATION OF GROUND WIRE ABOVE NEUTRAL ON POLES WITH BUTT-WRAPPED OR DRIVEN GROUNDS		
Scale: 3/8" = 1'-0"		Date: April 12, 1956
		M 30-2

DISCUSSION OF CONFERENCE PAPERS

(Part One)

Contents | Page

Presented at the 1957 Technical Conference for REA Field Engineers, New Orleans, Louisiana January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

TOWARDS BETTER SERVICE RELIABILITY

Discussion of paper by L. B. Crann

Howard M. Evans: Mr. Crann has presented a very comprehensive analysis of the methods to be used by rural systems in obtaining standards for service reliability as well as the most practical and economic means for establishing reliable service. Farm loads today are of such nature that disruption of electric service for even brief periods can cause considerable inconvenience and in some instances financial loss to the consumer.

Economic considerations must be foremost in justifying improvements to increase service reliability, just as they are foremost in any other type of system improvements. However, it is difficult to place a tangible value on the return from funds spent primarily to improve service reliability. In competitive areas, service reliability may mean the difference between staying in business in that area or losing out completely. Perhaps the greatest return will be in increased load growth due to confidence placed in the continuity of service by the members.

A well kept set of outage reports showing the consumer-hour outage on each section of a substation area is a must if service reliability standards are to be set. As more and more information of this type is accumulated througout the country, a standard should be approached which will serve as a goal to be reached. Naturally service standards will vary from system to system due to many factors such as physical terrain and incidence of right-of-way, types of loads being served, isoceraunic level of the area, ownership and control of transmission facilities, but proper evaluation should be made of these conditions and standards set accordingly for individual systems.

As suggested by the author, long range system planning should take into consideration service reliability as an integral part of future system design. In so doing, good service reliability standards may be reached with a minimum of investment.

Preventive maintenance on a routine basis will certainly pay dividends if well planned and if personnel is trained so that they will not pass by maintenance jobs which need attention. This can only be done satisfactorily when all personnel assumes the responsibility of doing needed maintenance as a routine part of their job. A large percentage of all outages is attributed to equipment and material failure which would not occur in many cases if normal maintenance practices were observed.

More basic research is needed in line design throughout the industry with emphasis being placed on service reliability. For instance, some rural systems have started using pin type insulators with higher voltage ratings than the minimum recommendation of the construction specifications. As a result, these systems have practically eliminated failures and outages due to punctures with resulting flashover to ground. In this particular case, the original investment is slightly higher, but the resulting savings in improved service with fewer trouble calls definitely justifies the increased cost. Also, trouble resulting from punctured insulators is one of the most difficult to diagnose thus causing outages of a longer duration than those from other sources.

Experience has also proven that the heavy, medium, and light loading districts as universally defined are not necessarily the proper guide for basic construction

criteria. Allowances certainly must be made for areas which suffer from severe icing conditions, even if the incidence is only once or twice every ten to fifteen years.

The author has established an excellent criteria to be followed in the application of sectionalizing equipment with respect to the number of consumer outages and also as regards the time required to isolate the trouble. The installation of excessive sectionalizing equipment presents economic problems from an initial investment standpoint as well as a continuing cost due to maintenance. Sectionalizing equipment requires maintenance with greater regularity than most other types of distribution equipment and failure to provide this maintenance not only constitutes a serious hazard to operating personnel but may cause prolonged outages.

Another important factor in service reliability that appears to be pertinent is the choice in application of three phase or single phase sectionalizing devices to three phase feeder lines serving areas which contain both large three phase and single phase loads. If consumer-hour outage is used as a strict standard in this case, single phase reclosers would supply the answer. However, service reliability is certainly affected by single phasing to three phase loads with resulting outages or possible damage to equipment. Should the large three phase consumer be subjected to possible motor burnouts due to the opening of a single phase recloser on his source of supply or should the small single phase consumer be penalized by an outage resulting from the operation and lockout of a three phase device due to a fault on another phase? These factors certainly require study and should be taken into consideration when service reliability standards are established.

Opening points in principal feeders should have disconnect devices other than hot line clamps. On larger sizes of conductor, it is almost impossible to handle jumpers with hot sticks and numerous cases of trouble have resulted where hot line clamps have worked or burned loose and interrupted service on main feeder lines when used on double deadends.

The author states that if a service reliability standard of one or two hour outages per consumer per year is to be attained, that no consumer should be more than 10 to 15 circuit miles from the substation. This, of course, is an ideal situation but not easily accomplished when only a limited number of power sources are available and loads in the outlying areas do not justify transmission facilities. Here again, individual evaluation must be given each system.

If service personnel are properly trained and equipped to meet most service calls, the duration of the outage can certainly be reduced. A fairly uniform plan should be developed as to the procedure to be followed when the source or a main feeder fails. In so doing, each man will be aware of his responsibilities without having to secure detailed instructions from the operating superintendent.

Source outages naturally affect more consumers than any other type of failure so additional care and planning as well as investment should be given to keeping both the number and the duration of these outages to a minimum. Advance planning and coordination of facilities between the power supplier and the distributor will eliminate outages due to faulty coordination of sectionalizing devices, maintenance of station equipment and the installation of equipment of inadequate capacity. All equipment which requires routine maintenance should have by-pass facilities to prevent outages and the investment to provide such facilities is more than justified.

Mobile substations are no longer a luxury to be afforded by only the largest utilities, but are now being produced in standard sizes at costs which will allow greater use.

A valuable asset to distribution cooperatives is the ownership of a mobile power plant. A unit of sufficient capacity to provide maximum flexibility requires a substantial investment but several cooperatives might jointly purchase such a unit to be shifted from system to system as needed. In some locations with high seasonal loads, the purchase of a mobile power unit may be justified by using the unit as a peaking plant and avoiding ratchet penalties in wholesale power contracts.

If 14.4/24.9 kv lines are constructed purely as express feeders they may offer some improvement in service reliability, particularly if an overhead neutral is used for shielding purposes. Construction of this type with the absence of distribution equipment to cause trouble should provide good service. It also allows shorter 7.2/12.5 kv distribution feeders from auto-transformer step-down stations of relatively small size.

Radial distribution systems certainly present less technical difficulties than loop or network systems but the duration of outages can often be shortened if alternate loop feeders are developed within substation areas and not operated as network system. These loops would serve as alternate supply routes to be used in case of emergency or at times when maintenance or construction is being performed on the normal feeder section. In many instances, a small additional investment in line and switching equipment will greatly enhance the operating flexibility of a rural system.

Tie lines between substations are certainly of value to any distribution cooperative if the operating problems presented by them are fully understood. To be economically practical, such distribution tie lines could not be designed to carry the entire substation load of adjacent areas, but would have the ability to serve a portion of the area. Such tie lines may sometimes be economically justified by shifting load from one station to another to offset wholesale power contract ratchet penalties. This is practical when two adjacent substation areas have different load patterns which make it of material benefit to shift loads on a seasonal basis. Safety precautions must be adhered to in arrangements of this type to prevent backfeeding into adjacent substations.

Mr. Crann has presented suggestions which will assist any rural system greatly in improving the type of service given to its consumers. Reliable service is not a thing to be gained overnight, but proper planning along the lines mentioned will produce positive results. Not only will the continuity of service be improved but the quality of the service as well.

Donald T. Lowery: Mr. Crann has provided an excellent discussion of factors affecting service reliability, and he has indicated the vital importance of service reliability to an electric distribution system.

As REA borrowers have gained in experience, there has been increasing recognition of the necessity for sound operation and maintenance practices. The determination of what are sound operation and maintenance practices for a given system, and the implementation of such practices requires continuing thought on the part of the system management. The safety and job training programs are continuing to make important contributions to improved service reliability by providing needed training for borrowers' personnel. Specialists from industry and from REA have given much assistance in this activity.

Complete and accurate operation and maintenance records can be very helpful in improving the quality of service. It is anticipated that among REA borrowers there

will be a growing emphasis on the keeping and utilization of such records in coming years.

The value of wide right-of-way in relation to service reliability is well-known; however, in some areas of the South, and elsewhere, borrowers' lines traverse lands used principally for the production of commercial timber, and in such areas it will be generally necessary to operate with a minimum width of right-of-way.

As Mr. Crann indicates, long-range system planning is helpful in improving service reliability. On the basis of an established long-range plan, a system can work effectively with its power supplier in an effort to arrange for the most desirable pattern of power sources for the future.

Good sectionalizing practices are of the utmost importance in attaining a high degree of service reliability. The necessity for proper maintenance of oil circuit-reclosers cannot be emphasized too strongly. With the increase in 3-phase loads, there is a trend toward installation of fuse cutouts on all taps off main feeders not provided with reclosers or sectionalizers; thus minimizing the chance that a fault on a tap will result in an outage on the main feeder. The use of fuse cut-outs or disconnect switches rather than hot-line clamps to open and close lines is increasing because of the greater degree of convenience and safety provided by the cutouts or disconnect switches. Another consideration is that upon re-installation after a line has been opened the hot-line clamp may not be tightened properly resulting in arcing and conductor burning. Among the REA borrowers with which the writer is familiar, the use of 3-phase reclosers is generally limited to those cases where the load involved consists principally of 3-phase motors, with relatively few single-phase consumers.

Designs incorporating the overhead neutral have been used in distribution construction in Louisiana for some time by REA borrowers and other electric distributors. Lightning conditions in the Louisiana area are among the most severe in the United States. The lightning performance of the distribution lines constructed with an overhead neutral in this area is reported to be very good.

Mr. Crann points out that the use of higher distribution voltages to serve increased loads generally does not tend to improve service reliability. He recognizes, however, that in some areas higher distribution voltages afford the only economically feasible means of providing service. As the loads on rural systems increase, it appears that system capacities will be increased both by provision of additional substations, with shorter, heavier distribution feeders, and by use of higher distribution voltages. There are indications that distribution voltages will go as high as 34.5 kv within a few years.

The REA field engineer can make a significant contribution by stressing to borrowers the importance of providing dependable service, and by doing everything possible to keep the borrowers in his territory informed concerning equipment and techniques which give promise of being helpful in improving service reliability.

POSSIBILITIES OF NUCLEAR REACTORS ON REA COOPERATIVES

Discussion of paper by Wade M. Edmunds

William C. Morris: Mr. Edmunds is to be highly complimented for his excellent and concise treatment of a wide ranging field. He has managed to include a maximum of the essential information concerning nuclear reactions and reactors in a minimum of space. It is highly recommended that the paper be retained as a sort of basic handbook to permit a better understanding of the many articles on the subject appearing in the technical journals.

Three REA financed cooperatives, Rural Cooperative Power Association, Elk River, Minnesota (Minnesota 70 Hennepin), Wolverine Electric Cooperative, Inc., 302 South Warren Street, Big Rapids, Michigan (Michigan 46 Newaygo) and Chugach Electric Association, Inc., Spenard, Alaska (Alaska 8 Chugach) have made proposals to the AEC for the construction and operation of nuclear reactors. These proposals have all been accepted by the AEC as a basis for negotiation and negotiations have proceeded through one or more contract drafts.

The participation of the cooperatives in the AEC reactor program is limited by the fact that REA cannot loan money for experimental facilities. This has been determined by a special opinion of the Office of General Counsel. In addition, arrangements must be worked out so that the participating cooperative is assured that power costs from the reactor will not exceed those from an equivalent conventional source.

The first problem is being solved through contractural arrangements, which provide that AEC will pay for and own the reactor and associated facilities. Contractural arrangements are also being developed to protect the cooperative against excessive operating costs.

To provide centralized and expedient handling of the special problems to REA, presented by these reactor projects, REA has assigned a team to each. These teams consist in each case of a representative from the Office of General Counsel, the area office concerned and the Electric Engineering Division.

In addition to the three REA borrowers actively working on reactor projects, the following borrowers, or association of borrowers, have shown their interest by obtaining access agreements with the AEC: (As of January 7, 1957)

Alabama Electric Cooperative, Inc.
Andalusia, Alabama

Seminole Electric Cooperative, Inc.
Madison, Florida

Boone County Rural Electric
Membership Corporation
Lebanon, Indiana

Corn Belt Power Cooperative
Humboldt, Iowa

Minnkota Power Cooperative, Inc.
Grand Forks, North Dakota

Ohio Rural Electric Cooperatives,
Inc.
Columbus 14, Ohio

Cooperative Power, Incorporated
202 North Downing Street
Piqua, Ohio

Oklahoma Statewide Electric
Cooperative, Inc.
Oklahoma City, Oklahoma

Central Kansas Electric
Cooperative, Inc.
Great Bend, Kansas

Kansas Electric Cooperatives, Inc.
Topeka, Kansas

East Kentucky Rural Electric
Cooperative Corporation
Winchester, Kentucky

Sho-Me Power Corporation
Marshfield, Missouri

Plains Electric Generation and
Transmission Cooperative, Inc.
Albuquerque, New Mexico

National Rural Electric Cooperative
Association
2004 Florida Avenue, N. W.
Washington 9, D. C.

Puerto Rico Water Resources
Authority
San Juan, Puerto Rico

The Texas Electric Cooperatives,
Inc.
P. O. Box 14
Austin, Texas

Dairyland Power Cooperative
La Crosse, Wisconsin

Wisconsin Electric Cooperative
Madison 1, Wisconsin

Lorain-Median Rural Electric
Cooperative, Inc.
Wellington, Ohio

An access permit allows the cooperative to receive classified information concerning nuclear power. This information is, of course, only available to cooperative personnel who themselves have been cleared and can show a "need to know".

It might be well at this junction to point out that most information needed by an engineer not directly concerned in the reactor project, is readily available in the unclassified literature. Indeed a study of the publications listed in Mr. Edmunds bibliography would be adequate even for many engineers actively engaged in nuclear power projects.

A recent survey tabulated 214 reactors in use or to be built in the United States. The money, time and effort going into these projects is sure to advance the day when we all will be using nuclear power in our homes.

The general size of the atomic program in this country can be gauged by the fact that our government has invested over $7,000,000,000 in nuclear facilities and about $2,000,000,000 per year are currently required for operation. All totaled, the people of the United States have invested over $15,000,000,000 in the atomic energy program. This of course, includes the military aspects as well as all the other facets. A program of this magnitude is bound over the long period to make tremendous contribution to the better living for us all, even though a large part of the work already done has a primary accent on military applications. It may be well to remember that practically every major military advance has in the long run become one of greater value to peaceful pursuits.

OPERATIONS AND MAINTENANCE PRACTICES

Discussion of paper by U. J. Gajan

A. A. Lee: We wish to commend Mr. Gajan on his excellent presentation of the functions and job accomplishments of management on a rural electric system. His thoughtful approach to the job and the well planned procedures he has developed to accomplish the many tasks involved certainly show effective management. We like his premise, that the objective of management is to provide abundant, dependable electric service at rates which will encourage the most widespread use, consistent with sound business principles.

The writer's comments on Mr. Gajan's discussions are not to be construed as criticisms of Mr. Gajan's presentation or methods, but instead are intended to bring out points of interest to our borrowers, field engineers and others in REA activities.

In a realistic approach to operation and maintenance practices, we must remember that the consumer wants electric power available at his installation when he needs it, in the quantity he needs, at satisfactory voltage levels, and at a cost he is willing to pay. Management must always balance these factors in its O&M practices against the necessity of keeping the system in sound financial condition. Excessive operating costs and over-maintenance practices may give superior service to the consumer and keep the lines in practically new condition, but may result in high rates which stifle development of the system and the community. So, we have to strike a balance acceptable to the consumer and the concept of "sound business principles".

We emphatically agree with Mr. Gajan that a practical program must be adapted to local conditions. Practices which give excellent results on his system may not work on others, especially the smaller REA systems. The Southwest Louisiana Electric Membership Corporation, according to our records, has over 3,900 miles of line and about 24,000 consumers, with a density of over 6 consumers per mile. This makes it one of the largest systems of REA borrowers. The typical or median REA system, as of December 31, 1955, was estimated to have 1,257 miles, 3,510 consumers served and have a density of 2.8 consumers per mile. When we compare these figures on size, it is apparent that methods which give excellent results on Mr. Gajan's system may prove highly impractical for a large number of other REA borrowers. This difference is sharply reflected in having large materials storage depots at several points, maintaining a complete vehicle service and repair shop, and equipping a shop and training personnel for major repair and servicing of automatic oil circuit reclosers. A smaller system would normally utilize commercial facilities or the services of their statewide associations in accomplishing these jobs. However, the principles of good management - effective organization, providing the proper tools, directing and coordinating - still apply.

We realize that it would have been impractical for Mr. Gajan to try to cover all phases and activities of operations and maintenance in a discussion of this nature. However, we would appreciate his comments on certain activities and details which have a bearing on successful operations and maintenance.

For instance, we consider safety and adequate job training as vital, and having a direct bearing on successful operations and maintenance. What steps are taken to train men to attain skill in their work, or are only skilled men employed? A poorly trained man is never a safe worker. What is done to make the employees

safety conscious? Any safety program, to be effective, must have supervision and be enforced. What is done to make foremen safety conscious? Does the line foreman hold tailgate conferences and give instructions on the safe way to do a job? What are the rules on using rubber protective equipment? Are safety regulations printed and does each employee have a copy?

In November 1956, REA sent out tentative recommendations on inspecting a pole before the lineman climbed it. These recommendations are not necessarily the final word on the subject but we hope they were useful. The inspections are not to be confused with planned inspections of pole lines for service life, but they should be coordinated. Do the linemen understand the brand marks on the pole? Especially, do they know what "X" on a brand means? This "X" indicates that a petroleum-creosote preservative was used, the so-called substitute preservative used in 1946-47 and part of 1948. This "X" should be a red flag. Poles so branded should be considered suspect until their condition has been determined. Serious accidents have occurred when some of these poles have fallen.

Combining pole inspection and groundline treatment with right-of-way reclearing appears to be an effective and low cost way of doing the job, where it can be applied. However, its effectiveness depends on the skill of the men doing the inspecting and treating. What mechanism is used to train these men, especially the foreman? When soil is removed from around the pole, is the backfill treated again, even though no full groundline treatment of the pole is necessary? Unsterilized soil against the pole may promote early decay.

The method of inspecting and treating is roughly the same as that given in REA Bulletin 161-4. The preservative used (one part penta concentrate to ten gallons oil) would require a high strength concentrate to produce the 5% penta solution recommended. We recommend using 2 to 3 gallons of this 5% penta solution per pole, while Mr. Gajan's cost figures indicate one gallon per pole being used. His preservative would have to be very toxic if reasonably effective protection is to be obtained. The preservative cost is quite low, less than one-half that of ready-mixed solutions. We feel that it is not good practice to skimp on the preservative used, as most of the cost is in labor, anyway. During refilling of the excavation around the pole, the preservative solution should be alternated with the backfill to sterilize the soil around the pole.

The replacement rate of 6% on poles 15 years old is about twice the normal rate, but conditions in the location may promote the growth of fungi. Were these poles in any one particular area of the system? When an unreasonable number of poles is found in a section, it might be well to determine the reason and the factors involved - age, species, preservative, treatment, supplier, and soil and moisture conditions. This information would form a basis for other inspections and might indicate corrective measures to be taken. REA also needs this type of information in its present study of pole life and failure rates in the Materials and Equipment Performance Survey. Factual data of this nature on large numbers of poles under various conditions, compiled over a period of years, could provide long-term operational and maintenance guides helpful to REA borrowers.

Keeping of adequate records is basic to any systematic operations and maintenance program. Mr. Gajan apparently operates on this basis also. His system covers a large area, has 31 metering points and apparently a diversity of lines. He mentions that consumer pole numbering is indicated in each ledger. We would appreciate some amplification on his system of pole numbering and how it is coordinated with consumer numbering.

Also, are outage reports summarized periodically, say by month or year, on consumer hours outage and outage hours per consumer? Such summaries could provide comparisons in quality of service by periods on sections of line and over the entire system. This type of summary is illustrated in REA Bulletin 161-1R1, Outage Records and Record of Operations at Sectionalizing Points.

A comprehensive program for maintenance of automatic oil circuit reclosers is described, including extensive repair and servicing facilities. Is the interval between servicing of reclosers determined only by counter operations, and if so, are fault magnitudes considered, or is a regular time interval scheduled? If servicing is on a time interval basis, is this based only on the manufacturer's recommendations or are local conditions considered? What is the normal period between servicing? Use of filtered oil is mentioned, presumably in reclosers. What is the minimum dielectric strength required before the filtered oil is re-used? Have any special problems been encountered in its use? Mr. Gajan does not mention maintenance of distribution transformers. While we do not recommend maintenance of distribution transformers as such, we do feel that they should receive servicing when removed from a service location and stored pending re-use. This may only involve repainting and possibly changing the oil. Is filtered oil used in distribution transformers? If so, is the acidity as well as dielectric strength checked? Keeping acidity below .3% is desirable to avoid formation of sludge.

What programs set up for checking voltage regulation at selected places on the system? Are voltages regulators used? Are capacitors used on the distribution system? If so, what procedure has been followed in getting analysis of power factor conditions and selecting locations of capacitor installations.

Are substations inspected and serviced by borrower? If so, what is the normal schedule of inspection?

We sincerely appreciate the privilege which Mr. Gajan has given us of obtaining an insight into the operations and maintenance program of a well managed rural electric distribution system.

J. W. Carpenter: Among other things, Mr. Gajan's talk clearly indicates that he is not letting troubles accumulate on his system. He evidently believes in locating them before rather than after an outage. Emphasizing the importance of planning, he also points out that operation and maintenance programs must be made flexible and adoptable to changes as necessity and circumstances dictate. We would say that such a program not only can be made flexible but must be. On the otherhand however, care must be exercised so that in striving for flexibility we do not loose sight of other requirements such as uniformity, accuracy, and the basic purpose of the various procedures.

It appears probable that the larger the system the more important it becomes to require high standards of accuracy as concerns outage reports. In most instances, reports are made but they frequently lack required information, are inaccurate, and do not contribute anything to efforts made to determine the cause of the outage or the cost. It is, furthermore, likely that many systems are loosing a chance to properly evaluate both the cost and the cause of outages by not summarizing outage reports periodically. We note that Mr. Gajan has worked out some appealing procedures for reporting, analysing, and restoring services after outages. What should not be overlooked is the fact that the outage reports carry enough information to permit a periodic summary of outages by type and cause. As the system load increases and emphasis on service continuity continues to grow, we suggest that the

number of consumers affected by each outage be recorded so that consumer-hours outage time can be computed for each outage. This procedure makes possible the evaluation of the various types of outages on a weighted basis common to all outages and which can be used for comparison. Analysis of consumer-hour outage data, rather than the number of outages only, is a more revealing method of determining which types of outages are causing the most outage time to the most consumers and how much expense to the cooperative is involved.

We have no comments with reference to the OCR operating and maintenance program other than to agree with the procedures as outlined.

As concerns pole replacement, it is recommended that all poles treated during the period 1946-48 be inspected below the groundline. Due to the scarcity of creosote oil after the war the treating specifications were revised to permit the use of substitute preservatives. The failure rate of these poles has justified inspection of them all on many systems. This matter involves all pine poles as used on Mr. Gajan's system.

Concerning routine line inspection, it is noted that an "inspector" checks all main line once a year. It would be of interest to know whether or not all inspections are made from the main office or whether each of the four districts do their own inspection. It would also be interesting to know how this system compared with the so-called "one-shot" inspection-repair crews which perform the line inspection and maintenance simultaneously. It is assumed that the merits and advantages of each method were considered at some time in the past.

It appears that effective procedures have been developed for the economical operation of equipment and handling materials. The procedure whereby material for the entire system is ordered every three months certainly has merit, particularly the practice of taking bids.

We assume that such matters as transformer records and repairs, meter records and test programs, substation inspection, and plant records, were omitted due to program time limitations. One subject was not mentioned, however, which is of prime and continuing importance to this group and, from time to time, to all cooperative managers. We refer to the matter of determing the quality of service, the counterpart of service continuity, which is measured in terms of voltage. To wait for consumer complaints is frequently longer than can be justified by economical operation but to make system improvements before they are needed may be even more uneconomical. The problem of timing system studies and system improvements is becoming more and more important as the loads grow and the money involved increases. The basic data for the most economical timing is a current set of system voltage records. It can be worth many times more than the expense of keeping the record.

In conclusion, there is one general comment to be made and which is implied from beginning to end of Mr. Gajan's informative presentation. Mr. Gajan's talk states that the type and accuracy of a system's operating and maintenance records are important indicators of the quality of it's management.

DISCUSSION OF CONFERENCE PAPERS

(Part Two)

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Presented at the 1957 Technical Conference for REA Field Engineers, New Orleans, Louisiana January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

ALUMINUM ALLOY CONDUCTOR IN DISTRIBUTION

Discussion and author's closure of paper by J. B. Roche

C. M. Wagner: Experience is the best teacher as we all know. The Southern Gulf Coast area of Texas is an excellent area in which to test all types of materials especially the metallic materials, it will also test man's ingenuity, patience, temper and finances with this one problem. A short statement of experience will be most helpful to establish the need for continued research and improvement of conductors.

In February 1942 four conductor miles of #4 - 6/1 ACSR was installed fifty-five (55) miles inland from the Corpus Christi Bay. This was found to be in excellent condition except for crystallization at the point of the armor rod clips, no corrosion was to be found though 1947 and 1948 were relatively dry years.

The local commercial power company related their experience with ACSR to be satisfactory in sizes of #2 - 6/1 ACSR with no oxide compound over the steel core was installed on 238 miles of distribution mostly fifty miles or more inland from the bays. Several short distribution lines were constructed ten to fifteen miles inland, and one line to the water's edge of Baffin Bay.

In July 1954 the number 2 - 6/1 ACSR fifteen miles inland was removed due to complete failure of the aluminum strands. 1951 and 1953 were extreme drought years.

In May 1955 eight thousand conductor feet of AAAC conductor was installed approximately fifteen miles from Baffin Bay. The sample here was removed December 26, 1956. There are unmistakable signs of corrosion, ACSR - #2 - 6/1 from the same area shows much more corrosion. A sample is not available installed at the same time in the same area, though a line with ACSR was constructed a few months earlier in the same area.

We believe AAAC conductor to be superior to ACSR. Our experience shows that it can be as easily installed as ACSR, sagging does not present any problem; nor do the fittings.

Very small amounts of copper in aluminum causes much trouble in the Gulf Coast Area of South Texas as Crouse-Hinds has admitted. Most aluminum pig as it comes from the reduction pots contains small amounts of copper. I suspect this AAAC does have some small amounts of copper.

Engineers from some of the wire mills that buy aluminum pig from the various aluminum companies, Kaiser, Reynolds, Alcoa and Alcan verify our contention that there is a difference in aluminum pig as it comes from the various companies. Wire made from aluminum pig from two different companies can not be joined into continous wires satisfactorily, I suspect there is also a difference though slight from different mixes in any one company's pot lines and that it is enough to affect the conductor in a heavily contaminated area.

We owe Kaiser Aluminum and Chemical sales a debt of gratitude. So far as we are able to learn they are the only fabricator and the only company interested enough to put forth a concerted effort to solve this problem. It is an excellent beginning. We hope they continue. This sample reveals AAAC is not good enough for our area.

To solve this conductor problem for the Gulf Coast area these questions will need answering.

1. What are all of the salts that are formed?
2. What is the outer orbit relationships of two dissimilar metal atoms when in physical contact with one another and in alloy form?
3. What D. C. Voltage exists? What is the polarity? How does the polarity change? What are the D. C. current values in the primary conductors? D. C. Voltages and currents are known to exist in the neutral of distribution systems.
4. What is the source of the D. C. currents? I suspect that D. C. current and voltages have many other origins than from the two dissimilar metals being in contact with each other.

Much valuable assistance has been rendered by the Technical staff of REA. REA has some very capable research engineers, though I do not know of the budget of REA for this most important department, I know that five times the amount of the present budget could and would be wisely used and would bring returns to the electric industry many times the cost to public and industry.

I trust also that the entire electrical industry will continue and even increase its budget for pure research.

I should like to hear from REA and the electrical manufacturers on how the cooperatives can assist them in securing a bigger budget for research.

J. N. Thompson: Two or three years ago we began to hear stories of various new types of aluminum conductor which were under development. I'm sure some of us got the impression that ACSR was going to be pushed out of the picture by one or more of the newer conductors. Mr. Roche's interesting treatment of the relative advantages and disadvantages of AAAC puts this matter into much better perspective.

If we think of the average REA-financed distribution system -- in rural, inland atmosphere, about three consumers per mile of line using 200 to 400 kwh per month -- we can soon see that there is little demand for a conductor such as AAAC. The prime consideration is long spanning, the lines are lightly loaded with respect to current density and there has been no trouble with corrosion of ACSR. Under the prevailing prices we would expect future construction or reconductering of existing lines to be done with ACSR for primary and bare secondary and with EC aluminum or triplex for services.

Into the make-up of the national average system, however, there goes a lot of non-average situations. We have possibly forty borrowers whose systems or parts of them are near enough to the ocean so that corrosion of ACSR is a problem. Some of these borrowers have abandoned all composite conductor -- ACSR and copperweld-copper -- in favor of hard drawn copper. There seems little doubt that AAAC can compete favorably in these areas.

In other areas where hard drawn copper has been used for other reasons, the eventual use of AAAC as a replacement is not likely. Although many of the lines originally built with No. 4 and No. 6 hard drawn copper must be reconductored to obtain greater capacity, ACSR would appear to be the logical replacement whether the lines are repoled or not.

There is a group of borrowers, most of them in the TVA area, who serve urban areas. With many of these borrowers extensive electric house heating is already an established load. Providing service for such a high load density requires large conductors both for primary and for secondary underbuild. Spans as a rule are shorter than in rural areas. This combination of factors has led several engineers to investigate the properties of the "light core" types of ACSR. These are more economical than the alloy conductor. However, if sufficient weight is given to the ease of splicing and deadending and particularly to hot line operations, AAAC should be attractive.

We have seen magazine articles reporting the experiences of two power companies with the alloy conductor. Both have stressed the fact that since it is harder than the EC strands of ACSR, the construction crews need not be as careful in handling it during the stringing operation. While it is certainly true that the alloy strands are much harder to scrape or nick, we wonder if a nick in a strand of AAAC would not be much more serious than a nick in an outer strand of ACSR. Do the manufacturers recommend the same degree of care in installing this conductor as with ACSR? Also, are armor rods and tape recommended in a similar manner?

We know that both hard drawn EC aluminum and medium hard drawn or hard drawn copper is quite sensitive to "ringing" or nicking with a knife during removal of weatherproof covering, for example. A sharp bend at this point will usually break the conductor. How does AAAC compare in this respect?

J. B. Roche: I'd like to first thank you gentlemen for your indulgence in hearing my story on our Alloy Conductor. In addition, I'd like to especially thank Mr. Thompson and Mr. Wagner for the remarks which they have made.

Mr. Thompson has very well outlined the places where we believe AAAC can and cannot be used competitively with other known conductors. To cover this quickly, we believe the areas where it may be used are those where there is a high load density, relatively high strength is necessary, or where corrosion is a problem. The main purpose of using All Aluminum Alloy Conductor is to give a high strength, single metal conductor which by its basic structure is strong yet corrosive resistant.

Mr. Thompson also brings out that in Urban areas some companies are using "light core" types of ACSR in short spans. This is a relatively interesting development in recent years but we have found in many cases that it may not be necessarily an advantageous solution to the problem especially if a tension limit of 2000# is imposed on the conductor. For example, if 336400 CM aluminum is used, all aluminum is just as reliable, more economical and in urban spans has as little, if not less, sag than the 18/1 ACSR. The main thought I'd like to express here is that if tension limits are imposed on conductor, be sure that all aluminum cannot be used before any construction of ACSR is selected.

As far as installation practices are concerned we believe any conductor should be handled as carefully as possible to assure that the conductor in the air is as near perfect as it can be. We would never counsel reduced care in handling any wire whether copper, all aluminum, ACSR, or Alloy. However, if an object strikes an aluminum strand with equal force as it strikes the alloy, the knick in alloy would be approximately half as injurious from the standpoint of deformation or knicking since the alloy is twice as hard as the all aluminum strand.

The second feature here is that once there is a knick, stress concentration results. This has been checked by notching the strands to 10% of the diameter and bending

the strand at the notch through 90°. On solid #6 H. D. Copper we found that it can withstand 1.8 bends while its equivalent alloy withstood 2.25.

The use of Armor rods or Armor tape is predicated on wear under ties, in the mouth of clamps or fatigue due to vibration. Rods are necessary if the stress in the strands approaches the fatigue limit of the conductor. For hard drawn aluminum the value is approximately 7000 psi, for H. D. Copper it is approximately 8000 psi, for the alloy conductor it is approximately 12,000 psi. Armor tape may prove unnecessary, but for the present we are advocating its use at this time. Future experience may prove that this practice is unnecessary and the practice may be abandoned.

I believe I have already covered the question of the effect of "ringing" conductor under the discussion of notch sensitivity. I believe at this point I'd like to stress that conductor, regardless of its kind, should never be "ringed". All manufacturers recommend that coverings should always be pencilled.

Mr. Wagner's comments on our alloy conductor are very welcome. His open minded approach to this relatively new material together with the corrosive condition in his area has proven to be a combination which is hard to beat when we decided to test all aluminum alloy conductor.

We ourselves have found in our corrosive test that standard no-ox-id is not the product to recommend for protection of conductor in corrosive areas. We have found that after a period of time this compound has embrittled and cracked and pockets are formed which can hold the salt water and cause local galvanic cells. Today there are other greases which can better do this job and show great promise for conductor protection.

Like Mr. Wagner we know that copper in aluminum can cause corrosive destruction in contaminated areas due to a local cell between copper and aluminum. As far as possible, however, both EC and alloy conductor are copper free alloys.

I'd like to be able to answer the four questions asked by Mr. Wagner concerning the salts formed as well as atomic structure and the effects of D.C. voltage in his area. However, the report on sample of conductor from his area has not as yet been received in the office and this information in unavailable at this time. This I believe is a subject which you may consider at a future meeting. I'm sure that our people would be most happy to discuss our experimental results with you.

INHERENT DESIGN FACTORS IN CONNECTING ALUMINUM CONDUCTORS

Discussion and author's closure of paper by C. G. Sorflaten

J. N. Thompson: We are indebted to Mr. Sorflaten and the other engineers of the Kaiser Company for their continuing study of aluminum and bi-metallic connections and connectors. Their reports make it possible for power distributors to understand the reasons for the many failures of such connections.

From the beginning of the REA program we have experienced these troubles in the form of radio noise, voltage flicker and eventual conductor burndown. The faulty connectors have in most cases been plated bronze connectors of the bolted type. The relaxation phenomena explained by Mr. Sorflaten is especially pronounced with this type of connector because of its relatively small area of contact with the conductor. Furthermore, the relaxation cycle is repeated if the connector is retightened to the original level. We have made some tests of this nature in which tightness was measured by means of the torque on the clamping bolt. This method does not measure the unit pressure or the total pressure applied to the conductor, but merely relates to the force used in making the connection.

We used short lengths of new conductor, No. 1/0 - 6/1 ACSR and No. 2 x 3 HD copper. Clamping bolts were tightened to 125 inch-pounds. Samples were not subjected to current or vibration. At the end of one month the torque necessary to start retightening was measured after which the bolt was again tightened to 125 inch-pounds. This operation was repeated after an interval of nine months and again after another period of six months. Typical results for one make of bronze bolted connector on copper-to-copper, aluminum-to-copper and aluminum-to-aluminum connections are tabulated below:

	Torque - Inch-pounds			
		To Retighten after Interval of:		
Type of Connection	Original	1 month	9 months	6 months
Cu to Cu	125	95	100	100
Al to Cu	125	60	70	80
Al to Al	125	55	50	65

These figures are representative of a number of makes of small bronze connectors tested.

In the same test aluminum and bi-metallic connections made with aluminum body connectors showed much less relaxation. We have attributed this to the generally larger dimensions resulting in a larger area of contact with the conductor. The following results were obtained with four makes of connectors on aluminum-to-aluminum joints:

	Torque - Inch-pounds			
		To Retighten after Interval of:		
Make	Original	1 month	9 months	6 months
A	125	90	100	125
B	125	100	125	130
C	125	120	125	140
D	125	80	100	130

Because of the effect of static friction and other factors we do not present these figures as an accurate index of the pressure exerted on the conductor. We believe, however, that this does offer a simple and useful comparison. We have found a definite relationship between performance in relaxation tests and performance in current cycling and under field conditions. As Mr. Sorflaten points out, a much greater amount of relaxation takes place at the higher temperatures caused by the passage of current through the connection. The extreme creep resulting from the use of dissimilar metals in the connector and conductor makes the use of aluminum or aluminum alloy mandatory in connectors intended for use with aluminum conductor.

Three possiblities are suggested as a means of adapting aluminum connectors to copper conductor:

a. The use of massive aluminum parts to distribute galvanic currents over a large surface.

b. Hot-flowed tin plating.

c. Heavy cadmium plating.

The first of these is gaining much popularity lately and certainly offers the most simple method of handling the problem. We have felt, however, that it relies too much on the use of a corrosion-inhibiting grease which may or may not be applied when the connection is made.

We have not had any experience with the use of hot-flowed tin as a plating on aluminum connectors. We would be interested in knowing whether there is a problem of obtaining a good bond between the two metals and whether hot-flowing is effective as a means of preventing porosity.

Heavy cadmium plating is apparently satisfactory as a protective coating for aluminum connectors.

We wonder why no mention is made of a copper insert of liner. It is true that a great deal of trouble has been caused by poor soldering of these inserts, but we have found that when properly soldered or when put in by other means these inserts have been satisfactory.

C. M. Wagner: Generally, experience has shown us in the Gulf Coast area of South Texas that compression splices are much to be desired over other past methods of splicing.

Much care must be exercised in making splices, this care is generally absent when contractors are employed.

Our experience of loop deadend clamps and U Bolt clamps has been sad, expensive and exasperating. The local commercial power company has had a similar experience, but until recently thought of it as a problem you could not do anything about.

Most connectors and fittings constructed of two dissimilar metals cause trouble, much trouble within four years and often in less time. Split bolt connectors were discarded long ago in our construction. Hot line clamps, parallel grove clamps used in the past have been a source of many outages and radio interference. Hot line clamps and other clamps caused power failures due to insufficient current carrying capabilities. Corrosion of the clamp and conductor reduced the current capabilities

resulting in burn downs. Various platings of clamps has not helped appreciably and often have increased the problem.

Many connectors used in the past have been too small, the current carrying capabilities have been lacking. Many have resulted in a cold flow of the conductor.

Recently much has been said for compression fittings, admittedly they make better electric connections, but pose a multitude of problems to the utility using them. Some of the objections are:

1. Lack of standardization.
2. Require many expensive tools and each manufacturer has his particular tool for applying the fitting.
3. Fittings and tools not easily available.
4. Warehousing is quite a problem since many sizes are required and often a new tool or a new die for installation.
5. Tools and dies easily get out of adjustment.
6. Difficult to tell if improper connection has been made.
7. Can not be used where removal is frequent.
8. Many are too small in contact area.
9. Too many fittings made of two or more dissimilar metals.
10. Abrupt projections with square corners which by corona generate radio frequency interference.
11. Absolutely no salvage value.

Colleges and laboratories try to simulate actual conditions but many fail to test under fault current conditions.

Bolted pressure fittings should have larger contact surfaces for applying pressure, this will increase current carrying capabilities, reduce cold flow of the conductor, absorb more effectively vibration thus reducing crystalization of the conductor.

We pose the question.
Do Galvanic currents entirely disappear? We do not believe so - electrolytes found in contaminated areas greatly increase this action and are not dissipated in the mass of the metal.

C. G. Sorflaten: Thank you for the kind remarks concerning the paper I presented at your conference in New Orleans. We are pleased at being asked to present this material to your convention and we are grateful that you found it of some value. We know that connectors have been a source of trouble in the past and I am sure that the interest that was in evidence in this group will certainly do a lot towards overcoming these difficulties.

We have inspected many connector failures in the field and they generally present evidence of either extreme heating or severe corrosion. Sometimes both are in evidence. In dry climates with little rainfall corrosion is often absent. However, in areas with normal to heavy precipitation corrosion usually accompanies connector failures. In highly corrosive areas corrosion appears on even the noncurrent carrying accessories such as dead-ends. The appearance of corrosion on connector failures is misleading in that it often leads to the belief that corrosion alone is the principle cause of failure. Such conclusions would require in connectors only the addition of a means to prevent corrosion to make a good electrical connection. It is not generally this easy to transform a poor connection into a good one, as other important factors exist. Most important is the element of creep which affects both

connector and conductor. Creep is induced or accelerated by heat and produces at first a minute amount of relaxation if the heat generated raises the temperature above normal operating temperatures. This tends, in time, to produce a loose connection with continually rising operating temperatures accompanied by higher joint resistances. Creep rate is a logarithmic function of temperature, e.i., it increases in multiples of 10 for given temperature rises. Thus, once a joint is started on its way toward failure it rapidly proceeds toward that end.

Corrosion accompanies this process when moisture is present, due to chemical activity with the joint. Chemical activity also proceeds logarithmically with temperature, e.i., it also increases in multiples of 10 with a linear temperature rise. Corrosion will greatly accelerate the connector on its path toward failure.

Since both creep and corrosion are accelerated by heating of the joint, the first consideration must be the limitation of quantities of heat that would raise its temperature above normal conductor operating temperatures. This is achieved by following the points listed below:

1. Applying sufficient pressure to develop liberal contact areas on the conductor strands.

2. A strong connector section that will not only apply this pressure but of such strength that the connector will not be affected by creep due to increased temperatures.

3. The connector should provide a long connector groove that closely approaches the conductor in curvature. This will assure a uniform distribution of contact area among all strands both internally and externally.

4. Connector designs should preferably be of aluminum for aluminum conductors.

The above factors are design characteristics of a fitting. With these factors and a sufficient number of fasteners to produce the clamping force required for the size of conductor used - it then remains for the user to properly apply this fitting to his lines. Too often this is not properly done and troubles arise due to faulty installation practices.

The majority of all connector failures inspected have shown that an important ingredient is missing. That ingredient is the all important sealing paste or connector compound. The use of this grease-like material accompanied by a vigorous wire brushing of contact surfaces to remove the oxide film is a necessary step to achieve a low initial joint resistance. Aluminum connector current carrying parts, such as spacers, should receive the same brushing technique as the conductor to remove the surface oxide film, unless these connector parts are plated with other metals or factory prepared and sealed by a sealing compound. By using this paste the voids that always exist in a bolted connector are filled with a sealing material that prevents moisture from collecting in the joint. Without moisture in the joint chemical activity cannot take place internally. The joint compound thus performs the dual purpose of protecting the contact surfaces and filling the voids in the connection to prevent moisture from collecting. The practice of using a grease sealing paste thus obviates internal corrosion in a bolted fitting which is difficult to control by design practices alone such as platings or massive sections.

TRAINING COURSES FOR METERMEN

Discussion of paper by Harold W. Kelley

Henry M. Alford: I have studied with interest Mr. Kelley's paper on "Training Courses for Metermen". He has made an excellent analysis and presentation of this subject. I do not think I can add any comments of particular interest as he has brought out the good points as well as the bad points of meter courses.

I would, however, like to add a few ideas I think are pertinent to this subject and emphasize some of the points brought out by Mr. Kelley. The selection of a meterman is very important. The man should be interested in metering and adept in working on small, intricate and delicate instruments. He should be schooled in the practical aspects of meter inspection, cleaning, repair, adjustment and calibration by working for some time with a good meterman of another cooperative or electric utility. He should be provided with or should provide himself with some basis meter text books from which with study he can gain theoretical training in metering. Then his attendance at a meter school will be well worth the time and expense involved.

There is no question in my mind but that the practical aspects of metering should be taught by on-the-job training and that meter schools should confine themselves to theoretical instruction and the discussion of problems in metering presented by those attending the school. I believe that meter schools at a university or college which is attended by many people from a number of different organizations provide an atmosphere in which the students by association can exchange ideas with other men of his particular interest. I agree with Mr. Kelley that an occasional visit to a meter manufacturing plant for instruction and inspection of manufacturing facilities would be very helpful in extending the education of meter personnel.

One thing I believe should be emphasized is that a meterman's training and education is never complete, regardless of his position in the organization and the number of years he has been engaged in this work. New developments are continually being made and new problems continue to arise from day to day. This makes it necessary for the meterman to study to keep abreast with new techniques, practices and developments in metering.

In closing, may I say that I feel that we in REA should continue to lend our support to these schools by our participation and attendance as this will indicate to our borrowers and their personnel our interest in their business.

TRAINING PROGRAMS FOR ENGINEERS

Discussion and author's closure of paper by H. R. Hill

F. E. Heinemann: The paper which Mr. Hill and associates have so ably presented covers two fields of training which are becoming more important as electric distribution loads grow. Both the voltage regulator and lightning arrester training programs will be influential wherever they are given in promoting a continuance of good electric service which is vital to good consumer relations.

The importance of the voltage regulator on electric systems looms large as the system loads approach conductor voltage drop limits as is evidenced by the great number of line regulator installations now on our borrowers' systems.

When electric cooperative systems were first constructed voltage regulators were not even required for substation voltage regulation let alone line voltage regulation since the loads supplied were small and the capacity of the feeders was generally far greater than required for the initial loads connected, consequently there was no need for the know-how in connection with operating and maintaining voltage regulators. However, with the promotion of the heavy electric energy using devices such as water heaters and pumps, ranges, electric heating and air conditioning systems, the capacity of the electric systems became overtaxed which without the use of voltage regulators or re-design of the systems reduced the quality of service through low voltage conditions. The resort to the use of the voltage regulator prior to re-design of the system has become widespread and it is expected that this will continue indefinitely which makes this device an important cog in every electric distribution system. Therefore, it is important that the operating personnel of our borrowers be given the opportunity of obtaining the know-how of operation and maintenance of voltage regulators by some method of training. The following is a quotation from a field engineer's report which is an indication of the need for such training: "As expected I found the regulators in this station on zero compensation and 120 volt flat output, Demand 650 kw so perhaps a relatively high compensation would be needed to get any benefit, but nobody on this cooperative apparently knows anything about regulator voltage adjustment or even cares about such matters". You engineers probably know of similar conditions prevailing.

It has also been stated by consulting engineers that because of the widespread use of voltage regulators some form of instruction in the operation and maintenance of this device should be made available to our borrowers' operating personnel.

This brings us to the subject of discussion. We believe, and no doubt you agree, that the devices used in this training program are very effective in getting the story across, especially the slides and demonstration kit which includes working models of regulators and their controls. These two aids certainly show how a regulator works in maintaining good voltage levels.

While there was insufficient time for the six $1\frac{1}{2}$ hour lessons to be given in detail at this conference a brief review of the lessons discloses that they appear to be well balanced and conducive to the students quickly assimilating the material involved. The first lesson covers the basic theory and principles of electricity, transmission and distribution systems, and voltage transformation which we believe necessary as a ground work for the following five lessons which include the construction and operation of both step and induction regulators, control systems and

types of connections. Finally, and most important to our borrowers, the installation, maintenance and safety in connection with regulators, is well covered.

In conclusion, it is our opinion from the office engineers' viewpoint that this training program should be made available to our borrowers on a Statewide basis by whatever method is most suitable. We understand that the Westinghouse Electric Company who is responsible for the preparation and assembly of this training program will either make it available on a fee basis or sell the kits to responsible groups. It is not practical for individual borrowers to purchase this training program but it may be practical for the Statewide Associations to sponsor schools with the aid of State Universities similar to the meter schools. Those borrowers in States where there are no Statewide Associations or similar organizations, should be invited to attend the schools in neighboring states, or organize in groups and have Westinghouse Electric Company conduct the school. The Allis-Chalmers Company also have an equipped demonstration truck with qualified personnel who travel throughout the country instructing groups in the operation and maintenance of regulators. This, though not as complete as the Westinghouse program, can be made available on request to the Allis-Chalmers Company.

The second training program "Power to Protect" is generally recognized to be primarily designed for electrical engineers since it is the engineer who designs substations, transmission and distribution lines and it is his responsibility for determining the type of lightning protection necessary for the equipment to be protected. When once the lightning protection is installed it remains in service indefinitely with little required maintenance. Therefore, such information contained in this program would not be of too great a use to the operation and maintenance personnel of our borrowers. However, the training program is complete and well put together. It is very informative and quite detailed in the theory of lightning arresters and their application. If made available to consulting engineers it should indirectly benefit our borrowers. If made available to our borrowers' engineering staffs it would benefit the borrowers directly. Correctly applied lightning protection equipment will naturally aid in the prevention of damage to equipment and will help insure continuity of service.

The color movies were interesting and covered the story of the lightning arrester from the time man first attempted to protect property from lightning to the most modern forms of lightning arrester equipment. Also, the step by step construction of the arrester familiarized one with its important features and the materials required in its manufacture. The movie "Traveling Waves" is designed to make the subject clearer and with the use of the wave analog machine does illustrate the phenomenon of disturbances of transmission lines. With the foregoing aids and the student manual the lighning arrester training program in its entirety consists of four sessions of two hours each and is conducted by the Westinghouse Electric Consulting and Application engineer.

We believe that there is much merit to this training program and in even its condensed form which appears adequate for the purpose intended and which has been given to you, there is no doubt in my mind that many of us have obtained valuable information about the lightning arrester application. It is suggested that this program be brought to the attention of our borrowers especially in those areas where lightning is most prevalent so that they may make the necessary arrangements for presenting the program to engineering personnel and groups of consulting engineers. It may be possible to interest the Statewide Associations in making the arrangements with the State Universities to present the program to groups of engineers and perhaps cooperative superintendents. Similar arrangements have been made for meter schools.

In conclusion, we believe that this training program is another valuable tool through which electric system engineers can apply the knowledge obtained, in reducing outages and protecting valuable equipment and improve continuity of service.

H. R. Hill: Mr. Frederick E. Heinemann's discussion of the paper "Training Program for Engineers" is very complete and comprehensive.

As a result of the discussion, following the presentation of the Training Programs and Mr. Heinemann's discussion, we wish to point out that these Training Programs are available from the Westinghouse Electric Corporation on a scheduled basis at no charge.

The two Training Courses, "Regulator Training Course", "Power to Protect", are available by contacting your nearest Westinghouse Electric Corporation Office who will determine their availability and schedule them for your use.

We suggest, where practical, that group training of instructors, either Job Training & Safety Engineers, or Statewide Associations, be set up so that training meetings can be held and scheduled with the demonstration kits and the cooperative would not be dependent on Westinghouse Engineers for instruction.

Westinghouse will make arrangements to train groups of instructors for this purpose.

The courses; being separated into various subjects, lend themselves to meetings to a particular group on a particular phase of the courses rather than having everyone attend the entire course when their interest is limited to a particular phase.

This could result in a saving of man hours of the personnel involved and still give maximum benefit of the courses.

The Regulator Training Course's audience could consist of engineers, maintenance personnel, installation personnel and application engineers. The Lightning Arrester Course is technical in nature and is designed primarily for system design engineers and application engineers.

Copies of the student manual for both courses will be mailed to the personnel in attendance at this conference in the very near future so that they will have an opportunity at their leisure to study further the details of these training programs and determine how and where they can most effectively be used by the cooperative.

DISCUSSION OF CONFERENCE PAPERS

(Part Three)

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Presented at the 1957 Technical Conference for REA Field Engineers, New Orleans, Louisiana January 14-18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

AN APPROACH TO LONG RANGE SYSTEM PLANNING FOR RURAL ELECTRIC DISTRIBUTION

Discussion and Author's Closure of Paper
By Harry Dewar

T. H. Hafer: It was a surprise to me to be invited to appear on your Engineering Conference program since I am not an electrical engineer. However, I am very glad to give you some of a manager's views on this subject. All my life I have worked for and with farmers and it has been a pleasure to have a part in bringing to them the electric service which they all so much appreciate. In my seventeen years with the co-op which I am trying to manage I have had several times to defend the engineers. As you all know when a lineman is having some trouble with some equipment or a line that will not hold on a stormy night, or even in good weather, he quite often wonders why the engineer did not plan this equipment in a way which would suit his work better. Sometimes he does more than wonder,--even letting out a few cuss words now and then. My answer to these men has always been that unless an engineer did some dreaming first the linemen would not even have a job. The linemen have learned to appreciate the fact that someone had to think and plan equipment before it becomes of use to mankind.

I want to compliment the REA Engineering Division and all those men in it who have done so much to make rural electric lines available. I know that at the start of the REA program there was a lot of really original thinking and planning. These conferences now are an indication that this original thinking has not stopped. Perhaps you have all had the experience that we have had in Illinois, I'm not sure. There the power companies questioned very much the type of lines which REA started the co-ops building and I used to be able to tell my friends how to tell a co-op line from a power company line, but in recent years I cannot do this because the power companies are now building the same type of rural lines which REA engineered in the early years.

While reading Mr. Dewar's paper I think in terms of our own Corn Belt Electric Co-op. We have experienced many problems which he mentions. I think he has covered the subject so thoroughly and with words suggesting so many "ifs", "ands", and "buts", that there are few possible situations which he has not thought of or factors which he has not suggested considering. His paper proved what I have said a good many times, "Engineering is not an exact science". It must include judgment based on experience.

Our co-op serves about 6,000 farms in a typical rural corn belt area with only about 100 commercials. These are grain elevators and a half dozen filling stations, motels and restaurants. Our growth has been so regular that this "exponential" rate of growth (a new word for me) has not worried us. Our load growth graphs which I will show you have helped me justify to our directors our expenditures for conversion jobs just ahead of the time needed. We have used a ten year plan made by a consulting engineer who visits us six times a year to advise us. Once a year we take voltage and load tests over our entire system to find the weak spots and then we do that part of the ten year conversion plan which will strengthen our system as needed. We, of course, change the ten year plans if load developments anywhere in the system indicate it is needed. It has been our pleasant experience that our conversion work has been spread so evenly that of the million dollars estimated for the ten year plan about $100,000 a year has been spent in conversion. This takes close planning but it works out very well because it gives us an opportunity to give our line crews and equipment steady and efficient work. I mention our experience because we have been following in general the plan Mr. Dewar proposes except we looked only 10 years ahead to start with.

SELLING THE BOARD

Now for the ideas, in the paper, with which I agree, those that strongly appeal to me and a few that raise a question in my mind and some comments on "Selling the Board", the manager's job. First, I agree that we need to set our sights on the long range--but for how long? It will take a super salesman to sell a farmer board of directors-conservatives, and it is usually a good thing they are, that you can foresee twenty-five years ahead. They are often afraid of those "economic" conditions that Mr. Dewar speaks of. As an example, we have tried getting our members to install heavy farm equipment such as hay driers, which take a lot of investment but they come very slowly. However, our load growth graphs from past years show such a continuous increase in use that even a conservative board has to agree that we had better plan for the future.

Here is a summary of the facts brought out by the graph which I believe will give as good an estimate of future use of power as a detailed survey of number of farms and equipment:

	1946	1956	Ratio 1956/1946
KWH Purchased	8,796,720	35,972,800	4.09
KWH Sold	6,631,052	32,203,563	4.86
Annual Peak	3,144 Kw	9,279 Kw	2.95
Annual Load Factor	31.94%	44.26%	1.39
Annual Losses	24.6%	10.5%	.43
Kilowatt hours per Member per month	118	460	3.90
Number of Members Served (End of Year)	4,892	5,834	1.19

Another important tool in selling a Board of Directors is a good map. It must be complete for operating but must be simple for giving directors the "big picture". I have found this map on display made on plastic and phased in color to be good for operating but a simple one showing only major lines and substations is needed for explaining system improvements to directors.

These farmer directors read about atomic energy plants coming! How soon?

The vision of savings in cost per kilowatt hour delivered with greater volume is a good sales point to use.

The economics of the long range plan can be explained to the board in terms they will follow. We have found our consulting engineering service very worth while and occasionally have the engineer at board meeting.

I like very much Mr. Dewar's cooperative approach, namely,--getting the engineers, managers, directors, local businessmen, G&T people in on the problem.

It is very important as Mr. Dewar says that our long range plan be flexible and that we change it as conditions indicate. With this promise in mind, a board of directors is more apt to be sympathetic.

I also agree on importance of the reliability of service. This means both in capacity available and continuity. I have heard of too many co-op managers, who cry about bottled gas competition and yet their lines go out of service or are taken out of service at the least provocation. Let's get 100% continuity built into these lines--that's a high standard but it must be our goal. I compliment our line crews because our outages have been getting fewer each year. This is a prerequisite to a successful Power Use Program.

OTHER PROBLEMS

One big problem Mr. Dewar does not tell how to solve is getting distribution, transmission, and generation planned together. We buy from the power company and furnish our substations. We have had to spend extra money to get dual wound transformers in order to be sure to be able to take the service we need because the power company has been in the process of changing their sub-transmission voltage. I believe that longer term contracts are one thing that might help. A continuous source of power is essential to long range planning.

If we look 25 years ahead will we then be serving most farms with three phase service? What about building three phase lines now instead of single phase or at least installing poles which will carry three phase when needed? I haven't been able to justify three phase service to every farm yet from my own figuring but I think more consideration should be given to it. This matter of whether to build an additional line or convert the present line is a very pressing problem. Mr. Dewar evidently has not been behind a desk all his life. He is very correct when he states that the right-of-way problem often settles the question.

Another very vexing question is the problem of trying to design and serve an efficient system where co-op lines and company lines are interwoven. Power companies in our area are exchanging territories but we cannot force our members to take service from a company, especially where the co-op rates are lower.

Yes, manufacturers of TV sets and other such equipment can help us a lot by making this equipment less critical of voltage. This is one of our big problems. A very high percentage of our voltage complaints are because the TV set does not give a good enough picture. I also agree with the other items of equipment which Dewar mentions, but why stop there? While we're "dreaming" how about more carrier or radio equipment to operate these OCR's without sending a lineman out. We find that in quite a high percentage of cases the fault on the line has disappeared by the time the linemen get out there, and the breaker goes back in service. Another one, how long are linemen going to have to climb poles? What about these hydraulic lifts which will put the lineman in a bucket right up to a tree or right up to his work at the pole? How about fiberglass poles and crossarms? We have a few of these crossarms to try out and I understand there are some poles being tried. My special gripe, however, and I must get it in here, is transformers and some other equipment made so that if a couple of sparrows get in a fight around the top of the transformer they blow the fuse. It seems to me that design engineers for rural equipment should remember that there are birds, squirrels, cats, and various other animals which get our poles mixed up with trees. We still have too many outages from birds and squirrels even though we have installed birdcaps. While writing this I notice an ad showing that one company has at last recognized this problem. Continuing equipment improvement is so important that we are cooperating with REA by reporting our equipment failures.

Oh yes, Mr. Dewar also mentions that maximum delay in installation of new equipment may be good so as to get the latest possible type. I'll go along with this idea if he will agree that we must be very careful not to delay too long. The power company in our area practiced this to such an extent their service was so poor that their customers came to us and begged to be hooked up to our line. I'm afraid a few co-ops may be tempted to do it. Co-ops started out fresh without any precedent of this kind. Let's don't overdo this delay and get caught short.

SUMMARY

Now in summary I do want to say that this paper on "An Approach to Long Range System Planning" by Mr. Dewar is a very thorough discussion of the subject. I think he has done an excellent job. If we follow his suggestions we will keep dreaming for the future, will weigh every possible factor as it might affect our plans, and will take care of each daily problem with our eyes on the future.

J. R. McCalman: Mr. Dewar is to be congratulated for this excellent discussion of the considerations involved in long range planning. The thoughts he has expressed are generally in agreement with the system planning guide now being considered for publication by REA. In most respects it discusses the long range planning problem in general terms instead of disclosing the intimate details of a particular method of planning.

It is apparent in several parts of the paper that Mr. Dewar is familiar with the problems peculiar to the TVA area and adjacent territory. Because of abundant low cost power and other factors peculiar to this area, loads and rural system development have reached an advanced stage compared to many other parts of the nation. These systems may be pioneering some of the maturity problems which will eventually arise in other areas. It is doubtful that these rather mature systems have avoided the problem of early obsolescence which all of us have noticed in the past. A sound program of long range planning will provide a better means of approaching system maturity without the waste that is possible with short range planning.

On page 2, Mr. Dewar points out that the "System Planning Engineer must necessarily be more than a technician" and must accept a responsibility for the basic data used in the study. These remarks recognize the changing status of the engineer in the rural electric program. Many of us can remember when construction skill was the primary ingredient of the rural electric engineers' qualifications. After World War II the same engineers found it necessary to learn system study techniques so that the system improvement construction needed for increasing loads would have a reasonably useful life. At this stage, he has still primarily a technician who produced a short range system design as a necessary preliminary to construction. If he expects to continue his usefulness to the maturing electric systems, the engineer must also develop long range planning skills. These skills will be similar and related to those previously employed but will not be identical. The judgement acquired in previous activities will be a most valuable asset but this judgment must be adapted to new methods and used with greater imagination. Imagination can be defined as the mental synthesis of new ideas from ideas experienced separately. Since very few of us have observed systems developed to the extent contemplated by long range planning this gap must be bridged by a more imaginative use of the judgement acquired from past experiences.

One of the last thoughts expressed was that rigid adherence to a uniform planning approach can produce something undesirable. In an activity such as planning, rigidity cannot be a virtue. However, it will be necessary for planners to use many techniques, recognized by the industry, as tools to accomplish their mission. It is desirable that the techniques used by the long range planner be stabilized as early as possible so that all concerned can become familiar with them. Now is the time for all engineers to examine recognized planning techniques to determine how useful they will be for long range rural system planning. However, we must recognize that there is considerable difference between uniform designs and the standardized tools used to create the designs.

Mr. Dewar has correctly emphasized that a long range plan is for use today. This can be misunderstood. In the past we have seen borrowers who wanted to build a 10 year plan as soon as the study was completed and the opposite extreme who lost the study in the files and tried to proceed without coherent planning. Both extremes can be equally disastrous to the economic health of the borrower. We must not forget that this plan will only be a guide for a professional evaluation of what should be done today. This evaluation may indicate that nothing should be built today or it may show that large amounts of construction should proceed at once.

On page 4 of the paper there is a comment about an engineer being "calibrated by the long range guide." The idea of a "calibrated" engineer seemed peculiar at first but after consideration, one realizes that the expression is very appropriate. In a way, we are all "calibrated" or conditioned for better efficiency by our experiences. After completing a long range system plan, the planning engineer is the one who is best qualified to provide the assistance needed by management in its year to year construction planning.

The long range planning objective has been stated in terms of completing a plan which will provide practical economic steps for the construction of principal electric plant components. This is one of the results of the planning process and of course, it must be accomplished. However, it may be better to think of the "Objective" in terms more useful to the management who are responsible for the economic welfare of the rural system. The following objectives, if kept firmly in the mind of the planning engineer, will help him produce a plan which will have a maximum value to management:

1. Expand the system by methods which will limit investments until load growth and revenue can support it.

2. Develop the system in orderly stages so that there will be a minimum of waste because of lines and substations becoming inadequate too early in their service life.

3. Recognize and implement opportunities to improve the quality of service.

4. Document the plan so that its logic will be apparent to non-technical personnel as well as other engineers. In brief, sell the plan by proper documentation.

In table 1 the annual cost of converting an old feeder is compared with supplementing the old feeder with a new one. If flexibility and reliability were the only benefits to be gained, the increased cost of building a supplementary feeder, might make this plan prohibitive for some borrowers. Economically less fortunate systems must concentrate on construction which substantially increases system capacity and permits a commensurate increase in earnings to pay for it. It is interesting to note that the annual cost of the old feeder plus the supplementary feeder is 43% greater than the annual cost of the converted feeder but the increase in capacity is about 50%. If the additional capacity is needed, this method of planning may produce an economical increase in system capacity in addition to the benefits of flexibility and reliability. In any particular case, alternative arrangements should be considered in the light of system needs and the economic factors peculiar to the system.

In the past, engineers who made designs for ten (10) years or less in the future were usually able to coordinate their plans with the wholesale power supplier. It was not difficult for generation and transmission cooperatives and power companies to make commitments for wholesale service within the periods covered by their own planning. When planning is extended to a much longer range, it may be difficult

if not impossible to secure advance commitments for wholesale service for the many new supply points needed. This will make it necessary for the planning engineer to examine the economic relationship between the distribution system and the system of the power supplier. In this way, he can assure himself that the long range distribution design has not imposed unreasonable problems on the power supplier. If this job is properly done, management can negotiate for new supply points with assurance. Many North Central Area engineers are already aware of the magnitude of the planning problem reflected on G&T borrowers because of some early long range planning activities in this area. Even though this planning problem will be great, there will be considerable benefit to the G&T management in getting an early view of what long range requirements will be.

Working on these and Mr. Dewar's thoughts has been interesting and instructive. Since the era of long range planning is practically here, we will all be thinking more and more about it in the year ahead.

E. L. Florreich: In the last paragraph of the foregoing paper by Mr. Harry Dewar, it concludes as follows: "THERE IS INCREASED CONTRAST IN CHARACTER OF RURAL ELECTRIC DISTRIBUTION SYSTEMS, AND WIDE VARIATION IN SYSTEM PLANNING NEED ON INDIVIDUAL SYSTEMS. RIGID ADHERENCE TO A UNIFORM PLANNING APPROACH CAN RESULT IN DECREASED VALUE TO THE INDIVIDUAL ELECTRIC SYSTEM, AND CAN RETARD DEVELOPMENT AND OPERATION OF VARYING LONG-RANGE PLANS NEEDED OVER THE INDUSTRY TO SERVE THE INCREASING VARIETY OF PROBLEMS INCIDENT TO SUBSTANTIAL LONG-RANGE GROWTH."

It is upon this conclusion that this discussion will comment, particularly with regard to consideration toward adherence to a uniform planning approach.

The author of this discussion is not opposed to long-range system planning, but questions the merit of the preparation of an evaluated plan including an over-all design for some systems, before definite information with regard to future load is available or can be foreseen.

In the past, consulting engineers have, consciously or unconsciously, given consideration to long-range expectations when ten-year system designs were prepared without evaluating or estimating what electrical facilities would be required in the future. Any plan is better than no plan, but whether or not it is evaluated will depend upon conditions to be encountered on the particular system.

The foregoing paper includes the definition of electric system planning as: "The process of determining WHEN, WHAT facilities should be provided WHERE in order to assure adequate electric service at minimum annual cost to the community." On a long range basis, such determination cannot be made for systems in areas where development does not as yet exist. Such areas are found insome parts of Arizona, New Mexico, and Texas, and possibly other states. What, When and Where future electrical facilities will be required are dependent upon many varying conditions of these undeveloped areas, such as development of irrigation projects, development of oil and mining deposits that may exist in varying quantities, whereby the development may be of long or short duration; industrial, and large commercial developments. In some cases, these latter developments occur from electrical facilities made available by competing private power companies; therefore, any long-range plan developed by REA borrowers must necessarily be coordinated with plans of these power companies, if any. Some borrowers consider this undesirable because in the coordination of plans, the cooperative divulges its plans, which makes it possible for the power company to extend competition. Where the power company provides the power for the cooperative, it is actually in a position to forestall, or to put obstacles in the way of the cooperative's plan.

In the State of Texas as well as elsewhere in the United States, there are systems that fit into particular categories, whereby long-range system planning may be feasibly possible, or may prove detrimental to the successful progress, development and operation of REA borrowers' systems.

Types of Rural Distribution Systems in Texas

1. Where the borrower's system is an integral part of the power supplier's distribution system, the continuity and quality of service to consumers is no better than that of the private power company's.

   On this type of system, power is supplied at distribution voltage from the power supplier's distribution system at metering points of delivery, which are controlled by the latter. In many cases, the power company will not permit the REA borrower to own the substation facilities, which are to be energized from the company's existing transmission line, but will provide the substations where the energy is purchased and the demand will amortize the investment. Then the power company is in a position to compete with the borrower, with electric facilities made possible by cooperative.

   Many systems are so thoroughly integrated with the power company's and so disintegrated within its own, that except for striving to obtain metering points at locations where, if possible-and-other-sources of power become available, cooperative-owned substations and transmission line can be installed some time in the future. One system in Texas is so thoroughly integrated with that of the power company's - which is the only source of power that is available - that even this plan is not possible.

   There are two consoling features of such systems. One, the borrower presently enjoys a reasonable rate for power, which varies from 5.5 to 6.5 mills; and, two, its capital investment in plant is less than would otherwise be possible. But the many disadvantages more than offset the advantages when consideration is given to possible future developments.

   For successful long-range system planning on such systems, the borrower will have to have full cooperation from the power supplier, which will also have to have a long-range plan, and also divulge its plans. It is doubtful that any such cooperation can be attained in most parts of Texas, if in any part.

2. There are some systems that serve irrigation and oil well pumping loads, as well as large commercial type loads, which are the predominant loads upon the system. Farm type loads are only incidental when consideration is given to system design requirements.

   Potential underground oil deposits are usually a matter of record, but when or where the developments will occur is unknown. The control of such development is vested in many. It may be the land owner. That may be the State of Texas; the lessor, oil companies, large estates, wild life preserves and many others. Likewise, the market for oil products and improved methods of producing oil, control its development.

   Irrigation and oil field development encourage other type loads, such as industrial, large commercial and domestic. But these loads, as well as their location, are dependent upon the location and existance of the oil pumping and irrigation loads, which are unknown. Nor can this be determined from a previously-existing pattern. To further complicate future long-range planning on this type of system it has competition from the private power companies that

operate in the same area. The cooperative's power contract with the private power companies contains a clause which prohibits it from serving non-farm, large power loads, except by being penalized with a demand charge. This contract clause is not always enforced, but the borrower has no knowledge of, or control with regard to whether or when it will be enforced.

3. There are borrowers whose systems cover vast areas of undeveloped land. Two of them in Texas are so large that it takes two days to make a round trip by auto from one end to the other. The areas contain many electric load potentialities, but it would be somewhat ridiculous to attempt to prepare a long-range system plan from the meager information available at this time.

   One of these systems extends from approximately Laredo to El Paso, Texas, which, by road, is 605 miles. It has approximately 60,000 square miles of service area. New construction is in progress in four widely separated areas.

   The other system has approximately 20,000 square miles of service area, which is divided into two distinct types of area. One has a large development in irrigation, where the growing season is approximately twelve months out of the year. The other contains large sections of undeveloped land where, presently, the existing load is for the pumping of oil, but it contains many future possibilities. Competition is had in both areas from one of the power suppliers.

   A system study has been completed (of the south system), and one is about complete for the north system. Both were based upon a ten-year forecast. Cost data indicates that the borrower has contemplated the request for an REA loan for $6,500,000 which would provide membership extensions based upon a five-year projection, and system improvements for the ten-year forecast. One can only surmise what the requirements would be if the study was evaluated on a long-range basis.

   These two systems are extreme examples, but there are other borrowers in Texas whose systems are similar in type, but they have less area to service.

   There are also systems in Arizona and New Mexico that follow the same pattern. In some, irrigation water is the prime requisite and provides incentive for anyone to inhabit the areas. When electricity becomes available, water is made available; then it is anyone's exaggerated guess what the load requirements will be, as well as when and where they will be.

4. There are systems which, from a power supply standpoint, are an integral part of power cooperatives' systems; therefore, any long-range system planning of the distribution borrower will have to be coordinated with that of the power type borrower. Any gross errors in load determinations made from meager information available, can become a catastrophe to both the borrowers, if electrical facilities are provided in accordance with a proposed long-range plan.

5. There are systems, where, because of drought conditions during the past four years or more, farm type membership has decreased and is continuing to decrease. System studies which have recently been prepared, based upon ten-year forecasts, have contemplated the gross membership and considered it to be static. Farm members have been replaced with irrigation projects, large power, commercial and oil pumping type members. Some growth in farm consumption has been contemplated, but the drought has caused the consolidation of small abandoned farms into larger ones. Qualified people predict that the abandoned farms will not be reoccupied even though the drought ends, and that mechanized farm techniques have reduced the need for tenant farmers.

If conditions are as described, the loads to be predicted in any long-range plan will have to be derived from large power, irrigation and oil pumping. It is difficult to predict what, when or where they will exist in the future.

6. In contrast with the previously mentioned type of system, there are systems that have large estates, which contain many sections of land, game preserves, state lands, etc. All are undeveloped; but it is generally thought that they contain underground oil deposits and have farming possibilities. It is expected that eventually the land will be divided into smaller units, but when this will be, is problematical.

This type of system is generally integrated with that of the private utility's distribution system. Some are in the vicinity of the Gulf of Mexico, and in the vicinity of ocean ports, and inland ocean ports, which are connected with the gulf by canals. Within the vicinity of the ports, industrial development is increasing rapidly.

The large industrial loads are supplied by the private utilities. REA borrowers serve the smaller loads; the influx of families to the country from the larger cities, and families and small commercial establishments in the vicinity of the newly created industrial sites. Such loads are competed for by the private power companies that supply power to the borrower's system. Even though it could be accurately forecast, what, where and when this future load would develop, the cooperative can expect to serve only portions of it, and experience alone will dictate what portions or quantity it will serve.

Some proposed canals and inland waterways are still in the planning stage; therefore, it is not difficult to see that long-range planning of electrical facilities to serve possible, but unpredictable loads, becomes a guess instead of an estimate.

7. Then there is the borrower's system that serves the typical small farm. There are two such systems in the writer's assigned area. Very little three-phase load is served. The farms are small, - (from 50 to 100 acres) - compared with most farms encountered in Texas.

It may be possible to provide long-range system planning on this type, but the management of one system has expressed the opinion that this is not desirable because of repeated requests for irrigation service.

8. There is still another type of system that is owned and operated by a municipality. Presently, all power, except for emergency requirements, is generated by the city. The rural system is a separate one from that of the city's and is operated by a separate organization.

This would appear to be an ideal situation for long-range system planning because the city is the REA borrower, and supplies the power for the rural system. Even under these favorable conditions, difficulties arise.

A recently completed system study of the rural system, which was based upon a ten-year forecast, indicated that required system improvements to provide for proposed irrigation load and estimated large commercial loads would put the cooperative in feasibility difficulty, although it is presently in good financial condition. The primary difficulty arose from the provision of adequate system capacity to serve an optimistic estimate of future large commercial loads, where the location of each was unknown. The irrigation load was provided

or estimated on a conservative basis to irrigate land that, during wet seasons, must have water pumped off; but, in general, it was the large commercial loads which determined the design requirements.

9. Another type of system, which in some respects is an unusual one, is where the borrower's system is engineered, constructed, operated and managed by a Texas power authority which generates, transmits and distributes power to cities and others.

   The two cooperatives, which are operated by the power authority, are very large ones. As of October 1, 1955, one had 4,828 miles of line to serve 14,142 consumers. The other had 4,217 miles of line to serve 10,210 members.

   They own much of their transmission line and substations, because, due to the rate structure of its power contract with the authority, they can purchase power varying from 6.5 to 2.5 mills per kwh in accordance with the demand purchased at primary metering points of delivery.

   These two cooperatives should be in an excellent position to provide long-range planning because of their close affiliation with the power supplier, which also operates their systems, IF it were accurately known where the large commercial loads would develop, what they will be and when they will be existent. Presently, at least, the operators prefer to prepare ten-year forecast designs, to continually scrutinize the proposed designs, and make changes as required.

10. There are systems, where the cooperative is a member of an REA power borrower, (although it obtains power from a private power company for portions of its system), which is integrated with that of the latter. The cooperative is supplied power by the power company and is billed for the power by the power cooperative at a greater rate than the power company rate.

    Knotty problems exist, even on ten-year forecasts, which will be further complicated should a long-range system plan be attempted. Without going into detail, which would be necessary to explain the many problems that arise under this arrangement, one can readily understand that the functioning of a long-range system plan under the conditions mentioned will be extremely difficult.

CONCLUSIONS

The author of this discussion is of the opinion that not only is it not desirable to maintain rigid adherence to a uniform planning approach for long-range system planning, but there are some systems in some areas where long-range system planning is not applicable, and if attempted, and followed, can actually be detrimental to the progress, development and operation of REA borrower's systems.

On systems where it is thought long-range system planning is not applicable, it is suggested and recommended that REA borrowers continue to have system studies prepared that are based upon ten-year forecasts which shall be reviewed and revised on a continuing basis, and have a complete review and redesign prepared once each year, which shall be extended for an additional year.

Harry R. Smith: Mr. Dewar very capably discusses many significant and important factors of system planning. Many discussions on system planning emphasize the long-range factor. In fact the title of Mr. Dewar's paper may imply that only the long-range part of system planning is discussed. However, he makes it very clear that long-range system planning for rural electric distribution is an integral part of system planning. Also considerable emphasis is put on determining the current year's

need for additional plant capacity and problems or questions that will be answered in developing these needs. Discussions with a number of engineers cause us to believe that detailed problems of the type illustrated in Table I should be answered as part of the development of the "current year's needs." The question of whether to add a parallel 3Ø 1/0 ACSR line or to convert the existing 3Ø 4 ACSR to 3Ø 1/0 ACSR should be answered as a part of the appropriate annual work plan and not by the long-range planning report itself. We should keep in mind that system planning consists of the following major steps:

1. Analysis of present system and basic data.

   The existing system is studied to determine its strong and weak points and to serve as a foundation for long-range planning. Basic data is reviewed to make sure it is correct and adequate and if supplemental data are needed arrangements for obtaining these are made.

2. Preparation of long-range plan.

   Management, in consultation with the planning engineer, establishes basic planning criteria such as future load levels and service standards. The planning engineer develops the long-range plan and makes sure it provides a logical evolution from the present system to the long-range system.

3. Annual review of long-range plan and development of annual work plans.

   The long-range plan is reviewed each year in light of actual developments to make sure that it still serves as a good guide for the development of the system, and is revised when this is found necessary. On the basis of the long-range plan, operating data and other factors, annual work plans are developed each year. These annual work plans are the short-range or conservative plans that control actual investment in plant additions.

If any of these major steps is omitted or treated lightly the effectiveness of system planning will be greatly reduced. These three major steps mean that system planning is a continuing activity. I fully agree with the author that system planning must be a continuing activity.

I also agree with the author on the necessity for good basic data and a good understanding of the existing system. However, the system's management should have the responsibility, for the major planning criteria such as the long-range load level, the load levels for various areas of the system and service continuity standards. Management should depend on the planning engineer for assistance and engineering advice in establishing the basic design criteria. Management should also take into consideration the recommendations of its own specialists and the plans for major activities within its service area mentioned by the author. The influence of the Rural Development Program, sponsored by the Department of Agriculture should not be overlooked. This program may be a very strong stimulus for many areas that are now considered low usage or marginal areas. The load levels for the long-range plan should be sufficiently large to require that all major components of the system be analyzed. Many of the basic design changes in themselves result in increasing the capacity of a circuit or area at least four times. Conversion of a single-phase line to three-phase of the same conductor size increases its capacity approximately four times. Cutting a circuit into two equal parts increases the capacity approximately four times. Cutting a circuit into three equal parts increases the capacity approximately nine times. Doubling the voltage of a circuit increases the capacity approximately four times. It is very difficult to properly plan major changes that in themselves result in capacity changes of four or more times if we restrict the

long-range load levels or basic considerations to loadings much below four times the existing loading. However, extremely large load levels would involve considerable extra work and would not be recommended. For most borrowers' systems long-range loading somewhere in the range of three to six times existing loading should be adequate for system planning purposes. The main objective of the procedure for analyzing the potential of the borrower's area as suggested by Mr. Dewar should be to make sure that long-range loading selected will not cause excessive repetitive planning and is sufficiently large to permit proper consideration of the improvement in capacity that is inherent in the possible basic design changes.

If we keep in mind that the long-range plan is a guide for the development of the system we may question the author's emphasis on determining the long-range growth or load levels for sections within the borrower's service area. Recognition should be given to areas where all available information indicates that there will be sizeable difference in the usages. However, I question the need for special consideration where the load levels for the various areas is expected to vary less than 20 percent.

Further expansion of the author's section on "Long Range Planning Approach On A Specific Project," would have made this paper even more useful. The author's technique for determining the optimum distribution feeder conductivity and load limit, the number of feeders and the approximate areas served by the individual feeder would be extremely helpful. Shortcut procedures for establishing such parameters should be satisfactory for long-range system planning and are needed to keep the costs of these studies from becoming too high for some borrowers. One approach that is being followed is quite similar to Mr. Dewar's. The engineer has studied and developed a good long-range design for a representative area of the system that fulfills the requirements of the basic design criteria. The engineer uses this as a guide or yardstick in analyzing the remainder of the system. Adjustments are made for differences in the load level, conductor size, etc, for the various areas of the system compared with the guide area. Another technique that may be useful is to make voltage drop calculations on the existing system using the long-range load levels. The amount of the voltage drop will assist in determining the types of system changes necessary.

Mention is made of the elements of annual cost to be taken into consideration in making economic comparisons. Most of us will probably agree that fixed costs should not cover both amortization and depreciation. The borrower should furnish the engineer data on its actual fixed cost. These should be reviewed jointly and data established for making economic comparisons. The following Table lists percentages of total plant value for the normal fixed cost elements for representative borrowers.

FIXED COSTS DATA
for
ANNUAL COST COMPARISONS

	Type of Facility		
Fixed Cost Elements	Distribution	Transmission	Substations
Interest	2.0%	2.0%	2.0%
Depreciation	3.0 to 3.5%	2.5 to 3.0%	2.5.to 3.0%
Insurance	0.5 to 0.75%	0.5 to 0.75%	0.5 to 0.75%
Taxes	0.5 to 2.0%	0.5 to 2.0%	0.5 to 2.0%
Operations and Maintenance	1.5 to 3.5%	1.0 to 2.5%	1.5 to 2.5%

When we talk of planning for future loads as large as six times the existing loads we could easily be disturbed if our first thought is that this may require increasing the investment by approximately the same multiple. However, there is good reason to believe that future investments will be more in the order of the following:

CAPACITY VS INVESTMENT

Capacity	Investment
1 Unit (Present)	1.0 Unit (Present)
2 Units	1.33 Units
3 "	1.6 "
4 "	1.8 "
5 "	2.0 "
6 "	2.2 "

From this table we would estimate that a system with an investment of $550.00 per member and a capacity of 300 kwh/member/mo. would have an investment of $1100 per member when the capacity is increased to 1500 kwh/member/mo. This favorable picture is based on the fact that practically all components of plant cost less per kva as the size or capacity of each is increased.

There is strong support for long-range system planning throughout Mr. Dewar's paper. Long-range planning is also gaining strong support in other segments of industry. For example, leaders in the automobile industry are planning 20 or more years ahead. From the following table you will note that the motor vehicles and parts industry turns over its capital five times to one turnover for the Utility Industry.

COMPARISON OF SALES TURNOVER TO TOTAL ASSETS IN VARIOUS INDUSTRIES

Classification	Revenue Equals Total Assets
Cooperative "A"	Once every $3\frac{1}{4}$ years
Cooperative "B"	Once every 8 years
Electric utilities	Once every 4 years
Primary iron and steel	Once every 11 months
Petroleum and coal products	Once every 9 months
Motor vehicles and parts	Once every 7 months
Food products	Once every 5 months
All manufacturing	Once every 8 months

If long-range planning, including the planning of facilities, is profitable to industries with low investment in proportion to sales then planning facilities should be very profitable for the utility industry with its relatively high investment in relation to sales. Considering the size of the investment in proportion to sales, can the management of a rural distribution system afford not to plan its investments in new facilities as wisely as possible?

Harry Dewar: Mr. Hafer states that on the Corn Belt Electric Cooperative they have been following successfully the general approach outlined in the paper - however, through looking ahead only some ten years as has been general on a majority of the rural electric systems. Mr. Hafer goes on to suggest logical reasons for presenting a longer range view in planning and then "take care of each daily problem with our eyes on the future." It is always worthwhile to receive comment from the man who has to continually eat the pudding!

It is reasonable to assume that within twenty-five years the majority of the large farms and many of the smaller farms will be served with three-phase power and this need should be recognized in long-range planning. Mr. Hafer is sound in questioning delay in adding system improvements to the point of absolute need. A reasonable margin of capacity, along with good service continuity, is possibly the best stimulus to load growth.

Mr. McCalman, Mr. Florreich and Mr. Smith speak from years of experience in electric distribution design and operations planning and are in position to evaluate the tremendous change experienced and indicated for the future in rural electric distribution. The four objectives for the Planning Engineer listed by Mr. McCalman are sound and each should be considered with respect to the conditions and needs of the individual system. As discussed by Mr. McCalman, both transmission and distribution systems can benefit from coordinated long-range planning for rural electric needs.

Mr. Florreich points out problems and possible limitations in long-range planning. These problems and limitations must be recognized. However, through the organized analysis of available data, on studies to date it is interesting that good results have been obtained that were not obvious or anticipated before the long-range study - even on systems where the engineer had completed as many as two earlier studies.

In long-range study, individual areas of large projects can be analyzed separately as well as part of project unit. Immediate gains from the long-range planning may be more evident in some areas of a system than in other areas of the same system.

The engineer can approach long-range planning with a freedom that is separate from the type of analysis needed when planning capital expenditure for immediate construction. In long-range planning, large blocks of potential loads, such as irrigation, can be considered in terms of an alternate design to the degree that available data and judgment justify the consideration. In actual plant additions, investment to serve these loads should be made only to the extent that there is reasonable assurance that such load, immediate and estimated future, will pay the cost of the additional investment.

Mr. Smith's suggestion for analysis of the present system, preparation of the long-range study plan, and annual reviews of the long-range and current need gives a logical approach to planning. The tables given are interesting and helpful.

The optimum load used in the long range design for the whole and for various sections of a system has relationship to existing load, to the future population and load potential of the area, and to the approximate time when the load may be realized with respect to the life of the units of plant additions planned. Recognition can be given to wide variation in load potential, such as for land suitable for high production irrigation farms and areas of probable industrial and residential expansion compared to areas experiencing substantial reforestation. As Mr. Smith points out, small increments of difference in load potential may be of negligible concern in long-range planning.

The reasonably limited experience to date indicates that wider experience in Long-Range Planning on rural electric systems over the next few years will develop many further techniques in both the planning approach and application.

As long as we remain a vital people we will continue to revise our approach to planning in the light of increased knowledge and new conditions.

DISCUSSION OF CONFERENCE PAPERS

(Part Four)

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Presented at the 1957 Technical Conference for REA Field Engineers, New Orleans, Louisiana January 14 - 18, 1957

U. S. DEPARTMENT OF AGRICULTURE

Rural Electrification Administration

ABOUT THE CONFERENCE .... The purpose of the Annual Conference for REA Field Engineers is to provide a forum for the discussion of engineering matters concerned with rural electric systems. The objective is to make available to field engineers an opportunity to share views and experience with other engineers who have developed a high degree of experience and specialization in specific fields. Likewise, the objective is to provide the specialist engineer with an opportunity to share his views with those who are facing the practical daily engineering problems.

To assure freedom for the development of ideas which may serve to improve the engineering of rural electric systems, the authors of papers and discussions have been encouraged to explore new ideas and new techniques and to prepare papers which reflect their own engineering judgment and experience. Such an approach may develop ideas which deviate from industry practices and REA policies and procedures presently in effect. It should be recognized, however, that REA policies and procedures as set forth in REA bulletins are still applicable unless changed in the light of the ideas and experience which may result from such papers or discussions.

R. G. Zook
Assistant Administrator

EXPLORATORY RURAL SYSTEM DESIGNS AT HIGHER KWH LEVELS

Discussion and author's closure of paper
By Thearl Essig and Harry Thiesfeld

Virgil H. Herriott: My discussion of this paper is from the viewpoint of a cooperative manager, rather than as an engineer.

The authors have, in their introduction, recognized several of the problems of management in developing system designs for higher KWH levels. Another point to consider, however, might be a need for more engineers who can and will accept the philosophy that exploratory system designs to serve loads at least four to six times present loads are useful and necessary.

Successful management of rural electric cooperatives must be based on continuous long range planning. The fact that the cost of their facilities is financed by long-term loans, which must be paid back in full during a stated period, makes it mandatory that sound capital investments are made which assure the most economical and effective utilization of the facilities once they are installed.

The need for engineers who understand and accept this philosophy is not the only problem, however. Management, in many cases, must also "see the light" and demand these exploratory designs before engineers will become sufficiently interested to the point of becoming competent at this type of work.

The cooperative by which I am employed is a part of a G-T system, all members of which are just completing their first exploratory designs for delivering an average of approximately 30,000 KWH per member per year. It took a considerable amount of time and discussion to get all of the member cooperatives to see the need for the studies and also a lot of time to convince some of the engineers that such a study could be made without the usual amount of detail involved in conventional system studies. The fact that the two different types of studies are used for two entirely different purposes was not easily understood.

I certainly agree that the system must be considered on the basis of its separate component parts--power supply, transmission and substations, distribution and consumers' facilities. The end result should provide the most economical and practical combination of these facilities over the long period. This best combination cannot be determined by a series of current short range studies.

The authors' statement that they "are more inclined to accept the viewpoing that three-phase service will continue to be the exception (and treated as such) for the average farm and urban consumer" may possibly be true for the present, however, this philosophy is not, in my opinion, consistent with the philosophy of having the cooperatives provide for their members an unlimited supply of power for their use wherever practical. I feel that the electrification of the farms of America has been held back due to limitations on the size and type of electric equipment that can be used by the farmer, rates which discourage widespread use and the unavailability of three-phase service. I think that if the attitude prevails that three-phase service will be made available as needed, and at a reasonable cost, that the use of three-phase service will fully justify any additional facilities required. Certainly long-range system designs are necessary in order to determine the lowest possible cost for such service.

Continuity of service, flexibility of expansion and economy in design are definitely of primary importance to management.

The authors' viewpoint on the advantages of loop or grid type transmission and radial distribution feeders as compared to a radial type of transmission with looped distribution feeders appears to have been borne out by the studies being made by the cooperatives in our area at home. It apppears that more power can be delivered more continuously and at lower cost by this method. Studies in other areas of the country may result in a different solution as being the best, however.

One of the objectives of management should be to expand the capacity of the system on a continuous and orderly basis so as to prevent premature investment as much as possible and to reduce obsolesence to the minimum. Our experience thus far with our exploratory designs indicates that it will be possible to develop annual or bi-annual work programs to accomplish this objective. Management will have to provide their engineers with accurate and detailed statistics on voltage and load conditions to assure this orderly expansion.

We all recognize that quality materials are essential to a long-lasting line. We must likewise recognize that quality engineering and management are equally important to a successful and long-lasting cooperative. Their mutual acceptance of the need and their individual responsibilities for exploratory system designs is, in my opinion, essential to the cooperative.

The Rural Electrification Administration is to be congratulated for the interest and activity which they have shown thus far in this area of engineering. I am sure that they will continue to point out the need for such exploratory designs and to continue to make their competent assistance available to the cooperatives.

Harold J. Christ: I represent Raymond H. Reed & Company, Consulting Engineers, of Columbus, Nebraska. Our consulting engineering services range over the states of Nebraska, Kansas, Colorado and South Dakota. We have been associated with the REA Program from its beginning. In these twenty years considerable variation of load characteristics have been encountered. For the major part of this time area coverage was in progress. For the last few years load growth rather than consumer additions has controlled system design. The methods of farming have also changed progressively toward more mechanization. This four state area has largely dry-land diversified farming but includes a large and growing amount of irrigation diversified farming, also wheat land farming and ranching. It is in this type of area that we have had most of our experience.

The Exploratory Design paper presents some interesting considerations. While our own approach to an Exploratory Design differs in some respects, we have arrived at the same conclusions generally.

We consider Exploratory design to be somewhat synonymous with Long Range planning and our observations are based on experience in this field.

Under current procedure system studies are correlated to Power Requirements data and the Form 215 contract suggests that the identical 2, 5 and 10 year periods be developed. Recently, we have amended these contracts to include an extended or Long Range development and have omitted one or more of the interim system developments. It is our opinion that something longer than the 10 year projection of loads is essential to proper planning. The design level of the exploratory plan does not

need to be correlated to any given years of load projection. The point I wish to make is that System Study data properly applied depends primarily on interpretation. The year certain loads develop is not important.

In selecting the multiple of existing loads to be used in an exploratory design a knowledge of the rate of growth for the system as a whole and segregated areas individually is needed.

It is necessary that the transition from the existing system follow an orderly pattern. The load multiple for any extended design must be large enough to evaluate the effect of load approximately 20 years hence, but not so large as to pass over any major phase of development. The multiple selected is very important for this reason. In our area it appears that loads exclusive of new connections are doubling approximately every 10 years but the rate is accelerating. A multiple of 4 or 5 is considered reasonable.

Certain economic considerations will affect any conclusions regarding an exploratory design.

Except in rural areas the consumers ability to pay has approximately kept pace with the dollar devaluation.

Electric construction costs have assumed a continually rising trend.

Considering the present reduced income in rural areas and ever rising costs certain short range construction investments may be considered expendable and should not be built with excessive capacity. Long Range facilities such as transmission lines and substations may well become a bargain as time goes on if properly placed. This points up the importance of exploratory design values.

If a given area needs only one substation for 5 years, 2 for 20 years and 4 for 30 years, a distribution layout to fit the 4 substation plan would obviously be uneconomical for quite a number of years.

Too many assumptions are made for too advanced a plan. We have seen dryland areas converted to sprinkler irrigated areas in only a few years. One system went from two wells total to 90 wells connected in one year. These wells are equivalent to the load of 10 farms each. This sort of thing must be evaluated in any exploratory design.

A limited "Iranian Desert" method of planning has long been our standard procedure. When developing a study involving various assumed kwh averages we have always started with the heaviest load development and worked back to the existing system. In rural areas varying from intensified farming in lush well watered soil to poor grazing land soil the existing system map is an excellent guide. The Iranian Desert plan assumes almost equal accessibility to all lines for operation and maintenance. In this respect is not applicable to many rural areas.

The state of South Dakota is embarking on an exploratory study involving the areas served by East River and Rushmore G and T. The Long Range study will furnish information for Retail Rate calculations based on much larger average usage than now obtain.

In discussing the Exploratory design paper we can give you a concrete example. The Charles Mix Electric Association is a member of the East River Electric Power Cooperative. We have just completed a Long Range study based on 2400 kwh per month

average. We also have completed a study based on 500 kwh and one at 1500 kwh average usage per month. The Charles Mix Association has a present average usage of about 200 kwh per month. They have for all practical purposes completed area coverages. They have no investment in substations or transmission lines.

This project is smaller than average having only 1550 miles of line proposed ultimately.

This project is entirely rural in nature and has little prospect of any heavy irrigation development.

Keeping this in mind we find that for each kwh increase in average monthly usage and investment of $550.00 will be required from now through 1980 based on current prices for construction.

Secondly, we find that the total plant investment will increase about $28,000.00 per year until about 1980 or in 25 years after which the annual investment will rise sharply.

During this period also the annual cost per kwh of sales will decrease from 42¢ to 6¢.

Now I would like to say a word or two about the mechanics of making a study on a Long Range basis. We have found that the use of area blocks such as townships is difficult. We would rather take existing feeders with known experience records and piece these together for forecasting usages. When project records are maintained on cards perhaps even on IBM cards the experience information to segregate areas for variable usage is much easier to work with. This also has been found to be no particular handicap in applying an "Iranian Desert" principle of design.

Many years ago Mr. Reed suggested that the future farm could well be powered by a small reactor dropped into an old well casing. While this was not a serious statement at the time, developments seem to indicate that plant sites of the future need not depend on available fuels, cooling water and transportation facilities and so may be more strategically located at load centers.

Once we assumed major transmission network locations were fixed. This may not be true in the future. In spite of this consideration a single Rural System is usually a small enough entity to warrant a transmission network within its boundaries with little chance of radical change.

In conclusion, I would like to say that cut and try methods have not yet been supplanted by any quick easy scheme in the development of any phase of a system.

A careful selection of the multiple of existing loads for exploratory designs is recommended.

An examination of the economic considerations is most important.

A periodic review of the system by qualified engineers is essential.

I would like to express our appreciation for the opportunity to participate in this program.

If time permits I'll be glad to answer any questions you may have.

Thank you.

E. A. Loetterle: First of all, I wish to compliment Messrs. Essig and Thiesfeld on their very excellent paper and presentation. Their efforts have produced a significant contribution to the art of system planning. Their approach to exploratory planning on the area basis, so far as I know, is entirely new. At least I have seen no duplication of it in any of the technical papers and literature I have read.

Rather than my presenting a technical discussion, I would like to discuss some of the more general aspects of the authors' paper and ask a few questions.

First, on page 1, the authors state: "There is a definite need for:

1. Investigation of system designs at consumptions 200% to 500% of existing loads, or even higher.

2. More detailed investigation of capabilities of existing facilities.

3. More efficient approach to preparation of exploratory designs than cut and try methods."

We are in complete agreement with these statements. They parallel very closely the comments made by consulting engineers whom we visited and talked to during the past year concerning long-range system planning.

A number of consulting engineers have already started to work on long-range system plans and we hope that more will start. So we should soon have a number of investigations of system designs at consumptions around 4 to 6 times present loadings. These planning studies presently under way are being considered as pilot studies. They may leave some things to be desired, but we hope they will be better than the old studies and we're sure that we shall all learn much from them.

With respect to the second need, that "there is a definite need for more detailed investigation of the capabilities of the existing system," we think so too and I'm wondering whether the authors have the same thing in mind. We are of the opinion that too often expensive system improvements, such as line changes, are made before the full capability of that particular part of the system is utilized. First, there is the tendency to generalize and because most of the substation area is in trouble we assume that all of it is and we work on the entire area. Then oftentimes too much reliance is placed on calculated data and because the average kwh readings are such that the calculated voltage drop figures indicate trouble, system improvements are installed. We feel that much more can be accomplished, in postponing system improvements, with actual meter readings, voltage regulators and skillful system operation.

With respect to the third need that "there is a need for a more efficient approach to preparation of exploratory designs than cut and try methods," we feel that better methods of making and examining exploratory designs are needed in order to reduce costs and to arrive at economical and practical long-range plans. The cut and try method generally used in system study preparation is not too practical for long-range planning. Better and less time consuming methods are needed. Some rules, formulae and information on the relationship between the various components of the system will help. We have been trying to develop such tools and we have been soliciting the help of some of the large manufacturers in this endeavor. We also have hopes that the consulting engineers will come up with some tools for developing and testing exploratory designs. To date, other than the author's paper, we can't report much progress; however, we are very hopeful that something will be forthcoming. For

example, there is good possibility that we can come up with a formula which will give guidance on substation areas for various load densities. A considerable amount of work along this line has been done by General Electric and Westinghouse engineers and there are a number of very good papers on the subject. However, most of what they have written pertains to utility systems with load densities many times that of our borrowers. We have assembled a packet of some of these papers for each of you. We think that you will find them interesting, helpful, and to say the least, thought provoking. However, we want to caution against their unqualified use. The formulae and data have to be checked out against conditions found on our borrowers' systems. We've started doing this, but the work hasn't progressed as far as I had hoped it would for this conference.

In their paper, under the heading Economy in Design, the authors discuss criteria by which the effectiveness of the design engineer can be measured and they list the following tests:

1. The ratio of the total plant investment to the total KWH delivered per year.

2. The total unit cost per KWH delivered to the consumer including the cost of power or generation, transmission, transformation of voltage, distribution, and service requirements.

3. The investment and annual cost per KW of consumer service capacity.

The first two, although they give some indication of the effectiveness of the planning engineer and are quite helpful, they are not a true measure, since they both are affected by load factor. A drop in load factor increases the cost of each KWH delivered, while an increase in the load factor reduces the cost per KWH delivered.

The value of investment and annual cost per KW of consumer capacity as a means of measuring the effectiveness of planning or comparing one plan with another appears somewhat questionable. The use of this test is illustrated in figure 5. Its use as an illustration to board members would be quite helpful, as Harry said, but I would like to point out that, normally two or more exploratory plans are prepared to serve the same given load. Any additional inherent future capacity in one plan is usually regarded as incidental as far as the economic comparisons are concerned. I agree that capability beyond the load level for which the plans are being prepared is considered when making a selection between the two plans. However, this additional capability need not be evaluated economically, because the intent was to come up with two exploratory plans with approximately the same load carrying capability. In conclusion on this point, unless you are comparing plans of different capabilities, I don't see how dividing by the KW will help in making a selection.

With respect to the author's quotation on page 4 from Mr. F. L. Lawton's paper, I want to make one comment. The quotation is as follows:

> "The paper concludes with the brief observation on the fact that the economic comparison of alternate facilities in the conventional manner, in view of the long-term decline in the value of the dollar, may not be too sound since the facility with the longest life, even though entailing greater investment, may well be the cheapest in the long run."

What he says is true, but what is more important, is that it all depends on when the investment is required. A plan requiring the investment of a dollar today is

1.219 times as expensive, based on 2% interest, as one requiring the investment of a dollar 10 years from now and 1.5 times as expensive as one requiring an investment 20 years from now. In addition, the added operating expenses on the prematurely installed facilities will tend to offset the decline in value of the dollar.

In closing, I again want to express our appreciation to Pop Essig and Harry Thiesfeld for their very fine contribution. It is a very interesting technical presentation. I'm sure we could spend all day discussing it. The data and relationships they illustrate between voltage drop, load density, feeder length and substation area size will be very helpful in gaining a better understanding of what is involved in long-range system planning.

The following is a list of questions which we didn't have time to discuss at the conference.

QUESTIONS

1. In Table I, there are two sets of demand figures for 1, 2, and 3 consumers per square mile at 2400 KWH per month consumption. Why is this?

2. In example 1. of the Appendix, in that portion of the formula for segment b, the figure 1. is added to the diversity factor, D_b. Why is this?

   The diversity factor for D_b (571 consumers) is 3.25 and for D_c and D_d it is 3.1 (285 consumers). Have the consumer figures become interchanged? Does b represent but one feeder out of the substation?

   X (the percentage of annual costs for various components usually varies). Does it make any difference that 10% has been used for all components?

   What is KW_a? Is it an indication of the over-all capability of the system? Does it vary for different segments (components)? How is it determined?

3. It is realized that Figures 3 and 4 were prepared to illustrate the development of substation locations served by radial transmission lines and transmission loops. There is however, some possibility of misunderstanding concerning the 300, 600 and 1200 KWH consumptions for the 2, 4 and 8 substation systems. Normally when the substations are doubled on a uniform system the capacity would be more nearly quadrupled.

Thearl D. Essig and Harry W. Thiesfeld: The authors are in agreement with Mr. Herriott and many others, judging from number of articles that are appearing, in assuming an optimistic attitude on consumer demands for 3Ø service at higher consumption levels. The negative attitude of the authors was formulated after reviewing the wide variation in local conditions on rural electric systems financed by REA. There is no basis for assuming the future holds no promise for universal improvement in the nation's economy and in technical arts which would justify widespread adoption therefore the writers will not contest his comments.

However, we wish to point to wide variation in rate of adoption that may be expected. For this reason we heartily agree long-range plans should be flexible and are taking this opportunity to emphasize the value of yearly review to keep abreast of all new developments.

We realize Mr. Herriott has given endless time and effort to research in the field of long-range planning and appreciate his straightforward comments. We feel he should be commended for his work in introducing and creating widespread interest in many sections of the country as well as his magnificent accomplishments in South Dakota.

Mr. Christ offered several practical suggestions to the application of the theme of our paper. Mr. Christ has had wide experience in design of rural distribution systems supplying rapid irrigation developments and we appreciate his views on use and frequent review of exploratory designs in planning improvements and on relating economics of the elective system to the area served.

We concur with Mr. Loetterle's view on more critical analysis of existing system capabilities through instrumentation checks, etc.

Because of lack of time and material for research our paper was somewhat limited in scope of treatment of relationship of investment costs to KW and KWH delivered. We were able to show the reduction in substation investment per KVA with increase in capacity but were not successful in illustrating accompanying increases in distribution investment.

We would suggest that continued study be given along this line to provide guideline criteria. The formula (1) in the appendix presents a means of evaluating the respective segments on any given condition. This, we admit, is on a static basis and still has to be applied to several designs. It is a tool to assist the engineer in making the most prudent selection. The purpose of converting costs to the consumers KW is to reflect the cost of providing capacity for the "average" or "typical" user. This eliminates the variable of load factor and recognizes the variable of diversity (or coincidence) factor as consumers are added to a line.

In reply to the specific questions:

#1. The upper row was left in the table through error in typing and should be scratched.

#2. The diversity factor figures were inadvertently reversed. It should have read:

$$D_b \text{ (max)} = 3.1 \text{ (285 consumers)}$$

$$D_c = D_d = 3.25 \text{ (571 consumers)}$$

Yes, "b" represents one feeder while "c" and "d" may represent more, two (2) in the example. The x factor is used in the example as a constant; however, it may vary with each segment of the line as management may select.

KWa is the selected design load for the system. The more commonly used design level is an assumed average KWH per month. KWa is determined by reducing the demand tables to one (1) consumer.

#3. Your observation is probably correct. The KWH figures were intended to be more illustrative than factual.

We again thank the discussors for their observations, questions and additional information.

RECENT CHANGES IN LINE DESIGN

Discussion and author's closure of paper
By James M. McCutchen

J. N. Thompson: Mr. McCutchen has given us a clear and interesting summary of recent changes in construction drawings and a discussion of some of the study leading to these changes.

As far as I know, this is the first time that the 7.2/12.5 kv drawings have undergone any extensive changes as a result of various kinds of research. Here we have had statistical research by Mr. Woehler in analyzing a large number of inventories. This enabled him to eliminate those construction drawings which borrowers and their engineers have found to be impractical for one reason or another. In the past, weeding out of this nature has been determined by individual judgment or possibly by an informal gallop poll.

In this revision Mr. Woehler also obtained comments and suggestions on the drawings from a much larger group than had ever been consulted on this matter before. The study and weighing of these comments was, I am sure, one of the most difficult parts of the entire job. On most topics, when you ask an opinion from ten different individuals you may get five or six "yes's", three or four "no's", and maybe a couple of "undecided's". If you ask ten individuals for opinions on a drawing, you are more likely to get two "yes's", one "no", and seven different suggestions for doing the thing in other ways. It is especially hard to satisfy everyone in a situation like this since every person who took the time to study and comment on the drawings can usually find a number of places where his suggestions apparently have been ignored. I think Mr. Woehler is to be complimented for the way in which he handled this.

Changes in the ground wire assemblies are, of course, the most extensive of those made in this revision. They have come about as a result of the tests described by Mr. McCutchen. The tests are an estension of the use of the steep wave front surge which has proven to be so valuable to REA in the study of insulators and arresters. There is no doubt that this wave is much closer to the characteristics of natural lightning than are the flatter waves of earlier tests on which many equipment and structure designs were based. Whether it is close enough to give us the true picture and whether the absence of a 60 cycle follow current is material remains to be seen. The objective of the new configurations is to keep the surge on the surface of the pole rather than to let it get inside the pole. It appears that they should accomplish this.

There is an old saying to the effect that there is no substitute for experience. In our work that might be altered to say that there is no substitute for experience with actual field installations in determining the suitability of a piece of equipment or of a construction drawing. To support this we can find many examples of ideas which seemed good in theory or in the laboratory but which failed when actually tried out. We can remember such things as the 600 va transformer, grip-flex ties and copper naphthanate preservative for poles.

On the other hand there are instances, perhaps not so obvious, where experience has not been utilized to give us answers we should have had. Our first ten or twelve years of experience with ACSR didn't teach us very much about aluminum connections or taps. There are possibly many places where we have fallen into the

habit of doing things in one certain way without really taking the trouble to find out why or whether there is a better way. We have taken pride in the way the "REA construction" broke away from the hide-bound "battleship construction" practices used by power companies. It may be that we are in danger of digging our own rut and falling into it.

There is need for all of us connected with the engineering phase of the REA program to take an occasional long-range, detached look at the book of drawings. I think we all become so concerned with location of a jumper or the exact wording of a note on a drawing that we have no time left to think about whether the assembly pictured really shows the best way of doing the job. The method in which this revision was handled seems to be a step in the right direction.

J. H. Phillips: Mr. McCutchen has performed a most praiseworthy effort in presenting this subject to us and we all realize and appreciate the part he played in the development of many improved assemblies. I think we may quite safely assume that much blood, sweat and tears went into these new specification booklets. All who played a part deserve a great amount of commendation and, in all truth, the many who will employ the specifications widely will owe much to the few who carried forward the task of detailed and sweeping review, and preparation of new drawings to effect these improvements. However, though these specifications are much improved in many respects, compared to the older specifications, it must be remembered and kept firmly in mind that a picture book, no matter how perfect, cannot be a substitute for the application of common sense and good judgment on the part of those who stake and construct lines.

Furthermore, I feel that those responsible for final approval of the assemblies in these specifications did not approve them with the attitude that the assemblies are inviolate and not subject to change when warranted. In other words, all of us, as engineers, should maintain open minds regarding the applicability of specifications and should, at all times, apply or encourage the application of good technical judgment in line construction, and if we do this we will have to effect some changes in these specifications.

In this connection, the following items appear to be of interest:

1. It is not clear how the A5-3 assembly can be installed on B4 and C4 units as indicated on the A5-3 drawing except in the bottom position where Grade B crossings are involved. As indicated on drawing A2-1 in Form 204, primary insulation levels must be increased according to the National Electrical Safety Code where primary hardware is grounded. If, on such crossings, the neutral were attached to phase deadend hardware, it would appear most incorrect to infer that the neutral deadend secondary clevis insulation would meet this NESC requirement. The answer would, of course, be to add a 3rd suspension insulator in the primary deadend where Grade B crossings are involved, and perhaps this should have been indicated on drawing M29-2 as in the case of A2-1 in Form 204.

   Incidentally, the 23KV insulated A2-1 should not be necessary on Grade B telephone crossings since, according to Bulletin 83-1 on grounding, the pole ground should not be carried to the pole top on such telephone crossings. This telephone company preference against pole grounds on crossings applies also to beefed-up assemblies such as the A9 or B9 and on both these drawings is a note suggesting the addition of pole grounds. Perhaps it would have

been better to omit the ground assembly note on the drawings since grounding units and pole top protection guides are included elsewhere in the specifications. As an added observation, it is logical to assume that many NESC insulation violations exist on REA lines on Grade B crossings, according to the foregoing where ground wire extensions are installed.

2. Drawings A9 and A9-1 are equipped with notes stating that conductor separations dimensions are minimum. There is no discernible connection between this note and the NESC, or to logic, and perhaps the note should have been omitted.

3. One object of the revised specifications was to enable conversion of assemblies with a minimum of effort. However, we still have no way to go from a B2 unit to a C2 unit or C2-1 unit without a complete disassembling and reconstructing of this assembly. It would be so much better to drop the B2 assembly six inches when installed to provide for adding the pole top pins for a 3rd phase. Is there anyone who would suggest that a cooperative not exercise this foresight and change the assembly?

4. On the C1-3 and C1-4 assemblies, compression bolts are specified in the pole top on angles of between 0 and 2 degrees and between 2 degrees and 5 degrees. On the C2-1, and particularly on the C2-2 for large conductors, on angles up to 30 degrees compression bolts are omitted. I believe that by all means they should be added though this would mean adding them before assembly of the double arms, and, though this would be an addition to the specifications.

5. Refer to the dual assembly drawing A5-1 and A5-2. A5-1 continues our long accepted practice of deadending a set of suspension insulators on an eyebolt. Now observe the A5-2 assembly. If we want increased clearance between the deadend insulators and the pole, it requires another eyebolt plus an anchor shackle and an eyenut. Why all the flexibility in the A5-2 that we do not have in the A5-1? Why not just use an extra long eyebolt on the A5-2 and get away from all the assembly work? It would be a lot simpler.

6. Refer to pole framing drawing M20. Our 7.2KV systems need the bottom pole top pin hole at its present location about like Custer needed one more Indian. What we need is for the bottom hole to be dropped six inches instead of three inches below the second hole. This would allow, in many cases, the addition of crossarms to existing lines without linemen trying to bore an arm bolt hole just below the pole top pin -- which often is attempted hot. Safety instructors have noted this needed change and I hope Mr. Shehee will comment on this.

7. In my opinion, a lift pole for triplex aluminum service should have been included in Form 804. Borrowers need such a drawing as triplex aluminum is widely used.

8. Ranch type service assembly guide M24-10 shows a 12 foot ground clearance requirement at the service attachment which is two feet more than NESC requires. Service assembly guide M24-1 should be

modified to show the 10 foot minimum attachment clearance to ground. It should also state the minimum drip loop clearance to ground per the NEC (which is 8 feet) and the fact that drip loop connectors should be taped conforming to NEC requirements--that is, if we want NESC and NEC requirements met.

9. An assembly drawing for adding a driven ground to an existing M2-12 ground should have been included which would show the recommended compression connection to the existing pole ground by means of a Nicotap or similar connector.

10. The C7 single deadend should conform to the C8 double deadend design where applicable; in other words, 60 inch angle braces probably should be used in most instances.

11. Use of hot line clamps in heavy main feeder line jumpers should be discouraged as being very poor practice. Also, in my opinion, hot line clamps have no business being installed on C4's or C4-1's or B4's, B4-1's, etc., which are vertical assemblies. Such clamps are included in the specifications also for double deadending multi-phase both single circuit and double circuit, and for "large conductors" which I assume means 4500 pounds breaking strength or greater. A hot line clamp is a poor connector at best, and I believe we would probably expect the worst application features on aluminum. According to the specifications, hot line clamps could be installed on lines of sufficient size to indicate they may be subjected to high fault currents--perhaps in the range of substation type oil circuit breakers.

    It seems to me that if provision for opening such lines must be provided, it should be by means of disconnects or gang switches. Any system operator attempting to use hot line clamps for such an application -- in view of the fact that these gadgets now are hung on the phase wires -- should deserve what sooner or later he will get, particularly if he believes hot line clamps are intended for hot connection or disconnection of heavy feeders. Why jeopardize heavy line investment and large load service continuity in such a manner? I suggest we set up maximum application limits for hot line clamps and use more disconnects and gang switches as common sense dictates.

12. On the E5-2, all three span guys should be bonded to ground or neutral -- not just one. Incidentally, the reason for the note on these guy drawings relative to adding ground assemblies is not clear.

13. On drawing G385-75 the nine foot minimum bushing clearance to ground should be shown. The drawing is misleading in regard to ground clearance.

14. The inside telephone pins and insulators on M24-4 should be removed to obtain required horizontal clearance according to the NESC.

15. On M33-1, -2, -3, -4, -5, -6, the four $\frac{1}{2}$ inch bolts through the pole on very short centers are specified for the attachment of the two braces. This looks like very poor practice to severely weaken the pole. It is suggested that a single bolt support be developed to

take both braces at the pole attachment.

I much appreciate the opportunity to offer the above comments and suggestions.

James M. McCutchen: The comments offered by Mr. Thompson and Mr. Phillips on this paper are appreciated by all hands. Mr. Phillips' comments pertain to specific drawings in the Specifications and offer an excellent guide to us and to the Committee as to where further efforts toward improvements in the assemblies can be made. As he points out, this is a continuing process as no drawing is inviolate or cannot be changed or modified to meet field requirements. These changes come about through the suggestions of you Field Engineers who work with them every day. If these shoes don't fit, then let the Committee have your measurements so that a pair can be cobbled for your feet.

One point was brought up by Mr. Thompson in the matter of connections on ACSR and further developed by Mr. Phillips in comment No. 11 on the use of hot line clamps in heavy feeder line jumpers which warrants detailed investigation. Some of these vertical corners, such as C4's, etc., should be buttoned up with permanent connections instead of tied in with hot line clamps. The use of hot line clamps on these complicated corners is an open invitation to the lineman to use these corners as switching stations; a definitely undesirable practice. The other excellent suggestions offered by Mr. Phillips are under consideration by the Standards group for inclusion in further revisions of the Specifications.

DISCUSSION OF QUESTIONNAIRE

An evaluation questionnaire was completed by the participants. The following is a summary of the replies. (Figures in parenthesis indicate the number of times the item was checked or listed).

1. How did you feel about this meeting?

   Wash: Excellent (8); Good (1) - Field: Excellent (14); Good (18).

2. What were the strong points?

   Wash: Well rounded program (5); Good presentations (5); Balance between Field, Washington and outside participation (3).

   Field: Good topic selection (12); Good presentations (11); Diversified representation, i.e., papers prepared by REA personnel cooperatives and manufacturers (9); Shows good planning (4); Papers well prepared (4); Inspection trips (4); Wide range discussion increased interest and brought out additional information (4).

3. What were the weak points?

   Wash: Not enough general participation (8).

   Field: The number of discussions and the length of them could be reduced in order to provide additional time to have more subjects presented (10); Not always enough time for discussions from floor (6); Too much detail of Westinghouse Training Course (5).

4. From which topic did you derive the most benefit?

   Wash:
   1. An Approach to Long-Range System Planning
   2. Operations and Maintenance Practices
   3. Towards Better Service Reliability

   Field:
   1. An Approach to Long-Range System Planning
   2. Aluminum Alloy Conductor and Inherent Design Factors in Connecting Aluminum Conductors. (These two were listed together so frequently it was not practicable to separate them in the tabulation.)
   3. Operations and Maintenance Practices

   Both Washington and Field listed "The importance of the topic" as the reason for selecting Long-Range System Planning as first choice. Operations and Maintenance Practices was selected because of the interest in hearing about the program from the Manager's point of view. Aluminum Alloy Conductor and Inherent Design Factors in Connecting Aluminum Conductors were selected because they provided information that was needed but not previously available.

5. What suggestions do you have for improving methods of presentation?

   Wash: Cut out some of discussion papers - allow more time for informal discussion (3).

   Field: Eliminate the prepared discussions and give more time for general

discussion by all personnel (7); More visual aids (2); Limit reading of papers to a minimum (2).

6. List specific ways in which any of the topics on the program will help you do your job better:

Wash: Better understanding of the problems and possible solutions (4).

Field: The majority of answers to this question referred to specific topics about which the field engineers gained more knowledge (Long-Range Planning most frequently). Other frequent answers were "improvement of advice rendered to borrowers" and "general growth in technical competence."

7. The presentations were generally pitched:

Wash: Too high (0)
Too low (0)
About right (9)

Field: Too high (0)
Too low (1)
About right (29)

8. Give your reaction to the use of outside speakers at technical conferences:

Both Washington and Field were unanimously in favor of outside speakers. However, a few persons cautioned against having too many outside speakers.

9. Was the time allocated to various topics generally:

Wash: Too short (3)
Too long (0)
About right (6)

Field: Too short (2)
Too long (1)
About right (28)

10. The most difficult technical or professional problem I face in my daily work is:

Wash: Long-Range Planning (3).

Field: Selling reluctant managers on long-range planning or on O&M or other specific need (10); Long-range planning (8); Keeping informed technically - because of the wide variety of technical problems (3).

11. List in order of preference, three cities in which you would like to have the next meeting held:

Wash: Washington, D. C.
Houston, Texas
Pittsburgh, Pennsylvania

Field: Houston, Texas
Dallas, Texas
Phoenix, Arizona

12. List the specific subjects which you would recommend for treatment at future meetings:

Wash: System planning (6); Sampling techniques for System Operation and Maintenance Inspections (2); Joint-use practices (2); Staking line (2); New developments in products and techniques in electric power field (2).

Field: Long-range planning (21); System protection (7); Transmission design (6); New developments in industry (5); Methods of improving operations & maintenance (4); Maintenance procedures (3); Discussion on capacitor application (3); Methods of reducing operating costs (2); Operating records (2); More about exploratory designs on system planning (2); Grounding problems (2); Economical loading of distribution transformers (3); Voltage regulation (2); Further approach to service continuity and reliability (2); Supervisory equipment & telemetering (2); Methods of "Salesmanship" of necessary programs to unenthusiastic managers (2); Substation design (2).

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